



# THE UNIVERSITY *of* EDINBURGH

This thesis has been submitted in fulfilment of the requirements for a postgraduate degree (e.g. PhD, MPhil, DClinPsychol) at the University of Edinburgh. Please note the following terms and conditions of use:

- This work is protected by copyright and other intellectual property rights, which are retained by the thesis author, unless otherwise stated.
- A copy can be downloaded for personal non-commercial research or study, without prior permission or charge.
- This thesis cannot be reproduced or quoted extensively from without first obtaining permission in writing from the author.
- The content must not be changed in any way or sold commercially in any format or medium without the formal permission of the author.
- When referring to this work, full bibliographic details including the author, title, awarding institution and date of the thesis must be given.

# **Mid-Late Holocene environmental change in northern Sweden: an investigation using fossil insect remains**

**Sara Khorasani**

**Thesis submitted in fulfilment of the degree of Doctor of Philosophy**

**School of GeoSciences**

**The University of Edinburgh**

**September 2013**

**Declaration**

The work presented in this thesis is the author's own, and, except where specifically stated otherwise, is not based on the published or unpublished work of others. The work has not previously been submitted for any other degree or professional qualification.

**Signature:****Date:**

## **Abstract**

For the first time, Mid-Late Holocene insect fossil assemblages were studied from inland northern Sweden, producing new evidence relating to both natural environmental changes and human impacts.

The insect fossil assemblages from natural deposits indicated extensive woodland with old and dead wood and a deep litter layer of decaying matter. Human impacts became apparent from the 1<sup>st</sup> millennium AD, when the landscape around many sites became more open, with elements of heath. It is difficult to determine whether these changes were driven purely by human activity, indicating subtle landscape change as a result of periodic exploitation, or if natural influences were significant in creating this landscape structure. If connected with human use, then the impacts of periodic exploitation can be seen to be subtle and localised, but notable enough to leave tell-tale signs in the insect fossil record.

These relatively subtle changes in the environment can be compared with the more severe effects found during periods of historically known permanent settlement, where extensively open and disturbed habitats are suggested in the insect fossil record. Species associated with arable and pasture land are restricted to the last few hundred years, in association with settled occupation.

The climate signal in the insect fossil record has been weak, and use of the Mutual Climatic Range method (MCR) has not revealed evidence of climatic fluctuations during the Late Holocene period.

## Acknowledgements

This research was funded by the Leverhulme Trust as part of the multidisciplinary project ‘Footsteps on the edge of Thule’.

Thanks go to my main supervisor Eva Panagiotakopulu, who has helped to guide and support me through the process, and to my other supervisors, Ian Ralston and Roger Engelmark, for their input.

Further thanks to staff at the University of Umeå, including Phil Buckland for providing the samples taken from the site of Sorsele. Paul Buckland is thanked for his help during fieldwork in northern Sweden.

The help and patience of Emma Tetlow and Kim Vickers were extremely valuable in the lab, and their willingness to share their knowledge is much appreciated. Gratitude is extended to Dr Graham Rotheray and Richard Lyszkowski for making great efforts to help me to identify rogue species during consultation of the National Museum of Scotland’s insect collection.

Finally, I would like thank my family, friends and office mates for their ongoing support and encouragement, without which the completion of this thesis would not have been possible.

# Contents

<b>1</b>	<b>Introduction .....</b>	<b>1</b>
1.1	Aims of thesis .....	2
<b>2</b>	<b>The Study Area.....</b>	<b>4</b>
2.1	Terminology.....	4
<b>3</b>	<b>Modern Ecological Setting .....</b>	<b>6</b>
3.1	Topography .....	6
3.2	Soils.....	6
3.3	Peatland.....	6
3.4	Vegetation .....	8
3.5	Climate.....	12
3.6	Flora and fauna .....	13
3.6.1	Invertebrates.....	13
3.6.2	Vertebrates .....	15
<b>4</b>	<b>Environmental History of Northern Sweden.....</b>	<b>18</b>
4.1	Natural environmental change .....	18
4.2	Vegetation development and climate.....	22
<b>5</b>	<b>Cultural Setting .....</b>	<b>31</b>
5.1	The archaeological evidence.....	31
5.2	Human impacts in the palaeoecological record .....	36
5.2.1	Early evidence for human impacts –hunters and herders .....	36
5.2.2	Early agriculture.....	42
5.2.2.1	South and Central Sweden.....	42
5.2.2.2	Northern Sweden .....	44
<b>6</b>	<b>Previous Palaeoentomological Work in Scandinavia.....</b>	<b>49</b>
6.1	The development of palaeoentomology in Scandinavia – an introduction..	49
6.2	Southern Sweden .....	50
6.3	Northern Sweden .....	54
6.4	Norway.....	55
6.5	Denmark.....	57
6.6	Finland .....	58
<b>7</b>	<b>Methodology .....</b>	<b>60</b>
7.1	Site selection .....	60
7.2	Sampling .....	61
7.3	Taphonomy and preservation.....	62
7.4	Sample processing .....	64
7.4.1	Insects .....	64
7.4.2	Plant macrofossils .....	65
7.4.3	Charcoal .....	65
7.5	Radiocarbon dating .....	66
7.6	Interpretation.....	67

7.7	Mutual Climatic Range .....	69
7.8	Quantitative analysis .....	71
7.8.1	Ecological groupings .....	72
7.8.2	Statistical analysis .....	72
<b>8</b>	<b>Norrheden .....</b>	<b>77</b>
8.1	Site description.....	77
8.2	Sampling .....	80
8.3	Dating.....	82
8.4	Preservation.....	82
8.5	Results.....	82
8.5.1	Phase I (0-8cm: Samples 2a and b).....	82
8.5.2	Phase II (0-6cm: Samples 3a, 3b and 3c).....	84
8.5.3	Phase III (15-21cm: Samples 4a and 4b) .....	87
8.6	Landscape reconstructions .....	90
8.6.1	Phase I (>6232 BC).....	90
8.6.2	Phase II (6232-6085BC) .....	91
8.6.3	Phase III (6018-5887 BC).....	92
8.7	Comparison with regional vegetation development .....	94
8.8	How open was the forest? .....	95
8.9	Disturbances in the Holocene forest .....	97
8.9.1	Grazing.....	97
8.9.2	Fire .....	98
8.10	Climate inferences from the insect fossil assemblages.....	98
8.10.1	Mutual climatic range .....	99
8.11	Comparison of parallel samples.....	104
<b>9</b>	<b>Sorsele.....</b>	<b>113</b>
9.1	Site description.....	113
9.2	Cultural history .....	115
9.3	Sampling .....	117
9.4	Preservation.....	117
9.5	Dating.....	117
9.6	Results.....	119
9.7	Discussion .....	123
<b>10</b>	<b>Akkajärvi .....</b>	<b>135</b>
10.1	Site description.....	135
10.2	Previous work in the local area .....	137
10.3	Sampling .....	139
10.4	Soil Profiles.....	141
10.5	Preservation.....	141
10.6	Dating.....	145
10.6.1	Column A – inside of the <i>renvall</i> .....	145
10.6.2	Column B – outside of the <i>renvall</i> .....	146
10.7	Results.....	147
10.7.1	Column B.....	147
10.7.2	Column A.....	152

10.8	Comparison between columns .....	154
10.8.1	Summary of environmental change .....	154
10.8.2	Cluster Analysis .....	156
10.8.3	Reindeer herding .....	158
10.8.4	Comparison with other palaeoecological evidence .....	162
10.9	Dung, foul and parasitic insects .....	164
<b>11</b>	<b>Gammelhemmet .....</b>	<b>172</b>
11.1	Methodology .....	175
11.2	Dating .....	175
11.3	Results .....	177
11.4	Discussion .....	183
<b>12</b>	<b>Gammplatsen, Lycksele .....</b>	<b>191</b>
12.1	Site Description .....	191
12.2	Cultural history .....	192
12.3	Sampling and Soil Profiles .....	197
12.4	Preservation .....	201
12.5	Dating .....	202
12.6	Results and discussion .....	203
12.6.1	Landscape change .....	203
12.6.2	Human activity .....	210
<b>13</b>	<b>Arvidsjaur .....</b>	<b>215</b>
13.1	Site description .....	215
13.2	Cultural setting .....	216
13.3	Methodology .....	218
13.4	Dating .....	218
13.5	Results .....	221
13.6	Discussion .....	227
<b>14</b>	<b>Quantitative Analysis .....</b>	<b>237</b>
14.1	Detrended Correspondence Analysis .....	237
14.2	Biodiversity .....	242
<b>15</b>	<b>Synthesis and Discussion .....</b>	<b>246</b>
15.1	The Mid-Holocene .....	246
15.1.1	The character of the natural landscape .....	246
15.1.2	Climate .....	249
15.2	Late Holocene environmental change .....	250
15.2.1	Natural processes and climate change .....	250
15.2.2	Signals in the insect fossil record. ....	253
15.2.2.1	Periodic exploitation .....	253
15.2.2.2	Permanent settlement .....	259
15.3	The current landscape structure .....	265
<b>16</b>	<b>Conclusions .....</b>	<b>269</b>
16.1	Environmental change in northern Sweden .....	269



<b>17</b>	<b>Future Study .....</b>	<b>273</b>
	<b>Appendix I - Futher Information on the Identification of Selected Species.....</b>	<b>276</b>
	<b>Bibliography .....</b>	<b>280</b>

## List of figures

<b>Figure 2.1</b>	The study area within Scandinavia .....	4
<b>Figure 2.2</b>	Map showing the location of the study sites in northern Sweden .....	5
<b>Figure 3.1</b>	Vegetation map .....	9
<b>Figure 4.1</b>	The altitude of the highest shoreline in Scandinavia .....	20
<b>Figure 4.2</b>	The timing of events/periods mentioned in the text .....	30
<b>Figure 5.1</b>	Summary of climate and vegetation changes and evidence of human activity in the inland north of Sweden during the Holocene.. ..	48
<b>Figure 6.1</b>	Map showing the central and southern Scandinavia sites mentioned in the text .....	59
<b>Figure 8.1</b>	Map showing the landscape around Norrheden.....	77
<b>Figure 8.2</b>	Satellite image of the sampling area, showing the extent of peat cutting .....	79
<b>Figure 8.3</b>	The sampled ditch at Norrheden.....	80
<b>Figure 8.4</b>	Soil profile from Norrheden with radiocarbon dates. ....	81
<b>Figure 8.5</b>	<i>Scolytus</i> cf. <i>ratzeburgi</i> thorax from Norrheden .....	87
<b>Figure 8.6</b>	BugsMCR temperature reconstructions.....	102
<b>Figure 8.7</b>	Average temperatures for January (1961 -1990) in northern Sweden.....	103
<b>Figure 8.8</b>	Average temperatures for July (1961-1990) in northern Sweden.....	1044
<b>Figure 8.9</b>	Cluster analysis using Bray-Curtis paired groupings .....	1066
<b>Figure 8.10</b>	Comparison of habitat groups represented in parallel columns from 0-8cm (Samples 2a and 2b) .....	107
<b>Figure 8.11</b>	Comparison of habitat groups represented in parallel columns at 0-6cm (Samples 3a, 3b and 3c).....	108
<b>Figure 8.12</b>	Comparison of habitat groups represented in parallel columns at 15-21cm (Samples 4a and 4b). ....	108
<b>Figure 9.1</b>	Map of the area around Sorsele .....	113
<b>Figure 9.2</b>	The location of the sample site in the natural landscape .....	114
<b>Figure 9.3</b>	The location of the Sorsele samples in the cultural landscape.....	116
<b>Figure 9.4</b>	The stratigraphic profile from Sorsele .....	118
<b>Figure 9.5</b>	The positions for elk with GPS collars in the area around Sorsele.....	127
<b>Figure 9.6</b>	BugsEcoFig. Diagram showing the abundances of species in certain habitat groups. ....	130
<b>Figure 10.1</b>	Map of the landscape around the sampling area at Akkajärvi.....	138
<b>Figure 10.2</b>	Akkajärvi sample location .....	139
<b>Figure 10.3</b>	Sampling inside and outside of the <i>renvall</i> at Akkajärvi.....	140
<b>Figure 10.4</b>	Column A sampling pit at Akkajärvi.....	142
<b>Figure 10.5</b>	Column B sample pit at Akkajärvi. ....	142
<b>Figure 10.6</b>	Column A soil profile at Akkajärvi. ....	143
<b>Figure 10.7</b>	Column B soil profile at Akkajärvi.....	143
<b>Figure 10.8</b>	Soil profiles of columns taken for insect analysis .....	144
<b>Figure 10.9</b>	Results of cluster analysis on the fossil assemblages from Akkajärvi using Ward's method. ....	158
<b>Figure 10.10</b>	<i>Renvall</i> , Najal, northern Sweden. ....	164

<b>Figure 9.6</b> BugsEcoFig. Diagram showing the abundances of species in certain habitat groups. ....	169
<b>Figure 11.1</b> Sample location at Gammelhemmet .....	174
<b>Figure 11.2</b> Profile of column .....	176
<b>Figure 11.3</b> Under the microscope snapshot .....	1822
<b>Figure 12.1</b> Map of Gammlplatsen the ‘Old Site’ .....	193
<b>Figure 12.2</b> Reconstructed kåta hut and pole store at Gammlplatsen .....	194
<b>Figure 12.3</b> Location of samples on map of the Old Site at Gammlplatsen.....	196
<b>Figure 12.4</b> Soil profile and description of Column A, Gammlplatsen. ....	198
<b>Figure 12.5</b> Soil profile showing context of Sample B at Gammlplatsen .....	199
<b>Figure 12.6</b> Kåta dwelling remains at Gammlplatsen. ....	199
<b>Figure 12.7</b> Location of column D samples at Gammlplatsen, looking northwest. .	200
<b>Figure 12.8</b> Soil profile of Column D at Gammlplatsen. ....	201
<b>Figure 12.9</b> 18 <sup>th</sup> century decorated clay pipe fragment from the Gammlplatsen site .....	202
<b>Figure 12.10</b> 8 <sup>th</sup> century pottery from the Gammlplatsen site.....	202
<b>Figure 12.11</b> BugsEcoFig. Diagram showing the presence of species in certain habitat groups.....	209
<b>Figure 12.12</b> <i>Rubus idaeus</i> seeds from Column A at Gammlplatsen.....	210
<b>Figure 13.1</b> Vegetation at the Arvidsjaur sample site .....	216
<b>Figure 13.2</b> Sample location at Arvidsjaur.....	217
<b>Figure 13.3</b> Soil profile with dates from the site of Arvidsjaur. ....	220
<b>Figure 13.4</b> Recovered insect fossil remains from Sample 4 at Arvidsjaur. ....	226
<b>Figure 13.5</b> The location of hearths and pits uncovered over several excavations at the Arvidsjaur site .....	232
<b>Figure 13.6</b> Elevated Phosphate levels at the Arvidsjaur site .....	233
<b>Figure 14.1</b> Sorsele DCA. Sample 14 omitted as outlier .....	240
<b>Figure 14.2</b> Akkajärvi DCA .....	240
<b>Figure 14.3</b> Gammelhemmet DCA. ....	241
<b>Figure 14.4</b> Gammlplatsen DCA.....	241
<b>Figure 14.5</b> Arvidjsaur DCA.....	242
<b>Figure 15.1</b> Environmental changes in the insect fossil evidence over the last 2500 years. ....	264

## List of tables

<b>Table 8.1</b>	Radiocarbon dating results from Norrheden. ....	822
<b>Table 8.2</b>	Results of BugsMCR analysis. ....	102
<b>Table 8.3</b>	Temperature envelope of <i>Hydraena britteni</i> . ....	103
<b>Table 8.4</b>	Temperature envelope of <i>Agonum gracile</i> . ....	103
<b>Table 8.5</b>	Temperature envelope of <i>Olophrum rotundicolle</i> . ....	103
<b>Table 8.6</b>	Adjacent samples from a depth of 0-8cm. ....	105
<b>Table 8.7</b>	Adjacent samples from a depth of 15-21cm. ....	105
<b>Table 8.8</b>	Adjacent samples from a depth of 0-6cm. ....	105
<b>Table 8.9</b>	Norrheden faunal list. ....	112
<b>Table 9.1</b>	Radiocarbon dating results from Sorsele. ....	118
<b>Table 9.2</b>	Sorsele faunal list . ....	134
<b>Table 10.1</b>	Radiocarbon dating results from samples taken from pollen cores outside of the <i>renvall</i> . ....	1466
<b>Table 10.2</b>	Radiocarbon dating results from insect fossil samples taken inside of the <i>renvall</i> . ....	147
<b>Table 10.3</b>	Radiocarbon dating results from samples taken from pollen Column D, inside of the <i>renvall</i> . ....	1477
<b>Table 10.4</b>	Results of cluster analysis using Ward's method. ....	157
<b>Table 10.5</b>	Akkajärvi faunal list. ....	171
<b>Table 11.1</b>	Radiocarbon dating results from Gammelhemmet. ....	1777
<b>Table 11.2</b>	Gammelhemmet faunal list. ....	190
<b>Table 12.1</b>	Size and frequency of charcoal in samples from Gammplatsen. ....	208
<b>Table 12.2</b>	Species list (seeds) from Column A. ....	213
<b>Table 12.3</b>	Faunal list bulk peat sample (B). ....	213
<b>Table 12.4</b>	Faunal list Column C. ....	213
<b>Table 12.5</b>	Faunal list Column D. ....	214
<b>Table 13.1</b>	Radiocarbon dating results from Arvidsjaur. ....	221
<b>Table 13.2</b>	Chronology of events at the Arvidjaur site. ....	231
<b>Table 13.3</b>	Arvidsjaur faunal list. ....	236
<b>Table 14.1</b>	Results of Fisher's alpha diversity index. ....	245

# 1 Introduction

This research was undertaken as part of the multidisciplinary project 'Footsteps on the Edge of Thule', which aimed to further current knowledge regarding past landscapes of interaction across the Arctic Fringe, where European settlers and indigenous groups came into contact. The principal investigators were Professor Kevin Edwards at the University of Aberdeen, Professor Ian Simpson at the University of Stirling, and Dr Eva Panagiotakopulu and Professor Andrew Dugmore at the University of Edinburgh. Three PhD projects have been undertaken as part of this project, including the research here discussed, and the completion of the other two PhDs is still underway. The period of the project grant has come to a close, and a final report completed, outlining the main results to date.

Investigated areas were southwestern Greenland, northern Norway and northern Sweden. Using a variety of palaeoenvironmental techniques, including pollen, soil and insect fossil analysis, the 'Footsteps on the Edge of Thule' project considered the visibility of past human resource use across the Arctic Fringe in the environmental record. It explored the possibility of assigning different signals to specific activities, aiming to distinguish between European and indigenous groups in the palaeoecological record. Furthermore, the impacts of different types of land use on the landscape were considered, and the influence of environmental changes and climatic shifts on resource exploitation and management assessed.

The focus of this PhD research is on the northern interior of Sweden. A key aim of the project reported here was to investigate natural deposits which pre-date human exploitation in order to develop a fuller understanding of the natural structure and disturbances of the Mid-Holocene forest, and establish a natural base-line against which later human impacts could be compared. Past climate in the Västerbotten area has been interpolated from evidence derived from much further afield, and the influence of climate on local vegetation development and human settlement is still not well understood.

Over the last few hundred years European settlers from the south and coastal areas of Sweden have moved further inland, into areas which were previously inhabited uniquely by the indigenous Sámi. The impacts of indigenous groups on the environment have recently been addressed in a few palaeoecological studies, demonstrating that the activities of hunter/gatherer and reindeer herding groups can leave tell-tale signs in the environment (Aronsson 1991, 1994; Hicks 1993; Carpelan and Hicks 1995; Hörnberg *et al.* 1999; Hörnberg *et al.* 2005; Karlsson 2006). Settlement of the inland zone by farming groups remains understood mainly on the basis of historical and archaeological evidence. The consequences of accelerating resource exploitation as farming groups expanded into the interior north from the 17<sup>th</sup> century AD onwards has been the subject of few studies.

The six sites studied in this research incorporate periods over the Mid-Late Holocene, and cover a range of sites with different cultural histories, with the aim of exploring environmental change and human impacts over this period in northern Sweden.

The research reported in this thesis uses the insect fossil record to address these understudied aspects of past environmental change and human impacts in northern Sweden. The habitat requirements of insects are becoming increasingly well-known, and the ability to identify remains to species level has been greatly aided by the growing modern comparative collections and availability of detailed keys. Both these developments provide ample opportunity and scope to utilise this method in an area that is understudied in terms of palaeoentomology.

## **1.1 Aims of thesis**

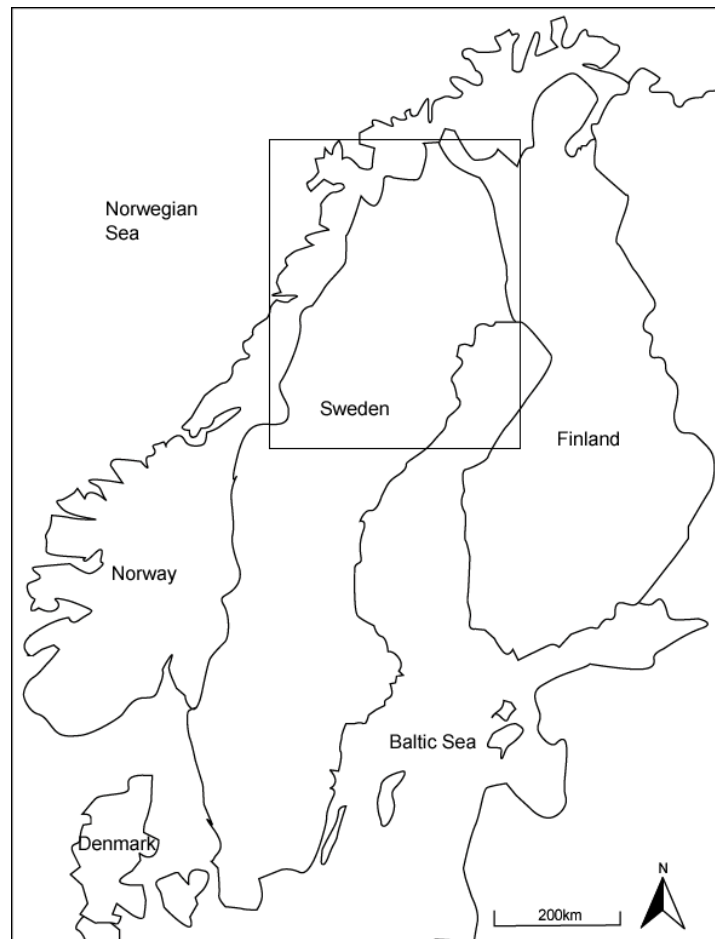
This research will use the insect fossil record to explore changes in the environment of the northern interior of Sweden from the Mid-Late Holocene. Climate changes, landscape structure and composition, disturbance factors such as fire and grazing, and human impacts will be studied. In particular, the following hypotheses will be tested:

- i) Environmental changes will be detected in the insect fossil record. Disturbance factors such as fire and grazing will be indicated in the insect fossil record by the presence of pyrophilic species and dung beetles. Climate changes will be witnessed in changing species distributions, and Mutual Climatic Range analysis will provide insights into past climatic regimes.
- ii) Indigenous Sámi groups will have had a localised and short-term impact on their environment not easily disentangled from the influence of natural environmental change.
- iii) The impacts of permanent settlement on the environment will be severe and the associated changes in land use and resource exploitation practices will be recognisable in the insect fossil assemblages.

## 2 The Study Area

### 2.1 Terminology

Northern Sweden is geographically part of Fennoscandia, which incorporates Sweden, Norway, Finland, Karelia and the Kola Peninsula (Lidmar-Bergström and Näslund 2005, 3). The sites studied are situated within the counties of Västerbotten and Norrbotten in northern Sweden (Figure 2.1 and Figure 2.2), encompassed in the geographic areas of Finnmark and Lappmarken, both of which are old names referring to the areas of northern Scandinavia inhabited by the Sámi. The Sámi are the indigenous people of northern Scandinavia and the Kola Peninsula. The term ‘Sápmi’ is often used to refer to the areas of traditional Sámi habitation and cultural associations across the north of Sweden, Norway, Finland and parts of Russia (Ojala 2009).



**Figure 2.1** The study area within Scandinavia. The highlighted area is shown in detail in Figure 2.2.





**Figure 2.2** Map showing the location of the study sites in northern Sweden (circles) and other sites mentioned in the text (crosses). Sites 1-7, studied by Aronsson (1991), are 1. Saivo 2. Akkajärvi 3. Atjekåive 4. Storsaivis 5. Östra Kikkejaure 6. Lamburtjärnarna 7. Arvträsket.

### **3 Modern Ecological Setting**

#### **3.1 Topography**

Most of the northern landscape is situated above 200m asl (Lidmar-Bergström and Näslund 2005, 7), and is presently dominated by coniferous forest, extensive plains, and mires (Helmfrid and Östman 1996, 10). In the interior of northern Sweden the landscape is punctuated by residual hills, reaching up to 400m, products of the weathering and erosional processes which have occurred over millions of years (Jonasson 1996, 17). The main rivers of northern Sweden flow parallel to one another, following the gentle slope of the landmass from west to east (Figure 2.2). Many of these rivers are now used for the production of hydroelectric power. Along the coast of northern Sweden fluvial and glacial valleys exist within a generally flat landscape (Jonasson 1996, 17). Further south the landscape is dominated by the flat sub-Cambrian peneplain (Jonasson 1996, 12). In the west, the coniferous forest gives way to birch forests and extensive plateaus, with the high mountains of the Scandes bordering Norway (Jonasson 1996).

#### **3.2 Soils**

Northern Sweden is covered in many parts by a medium-grained till, deposited by glacial action, lying directly on the bedrock, although many of the valleys are infilled by glaciofluvial sediments, and clay-silt deposits which were once submerged beneath lakes or the sea now provide valuable agricultural land along the coast (Jonasson 1996, 30; Seppälä 2005, 54-56). In the northwest mountain regions a thin cover of weakly developed soil may cover the bedrock (Jonasson 1996). Most of Sweden is covered in haplic podzols of variable depths, formed within the coniferous woodlands; these soils are a product of high precipitation and cold temperatures. The clayey soils host deciduous woodland in parts of the south and in coastal areas, producing cambisols (Jonasson 1996, 33).

#### **3.3 Peatland**

In the interior, the blockage of drainage by permafrost action has played a significant role in the formation of peat bogs and fens. Peatlands cover more than a quarter of the land in Sweden (Montanarella *et al.* 2006). Raised bogs are the most common

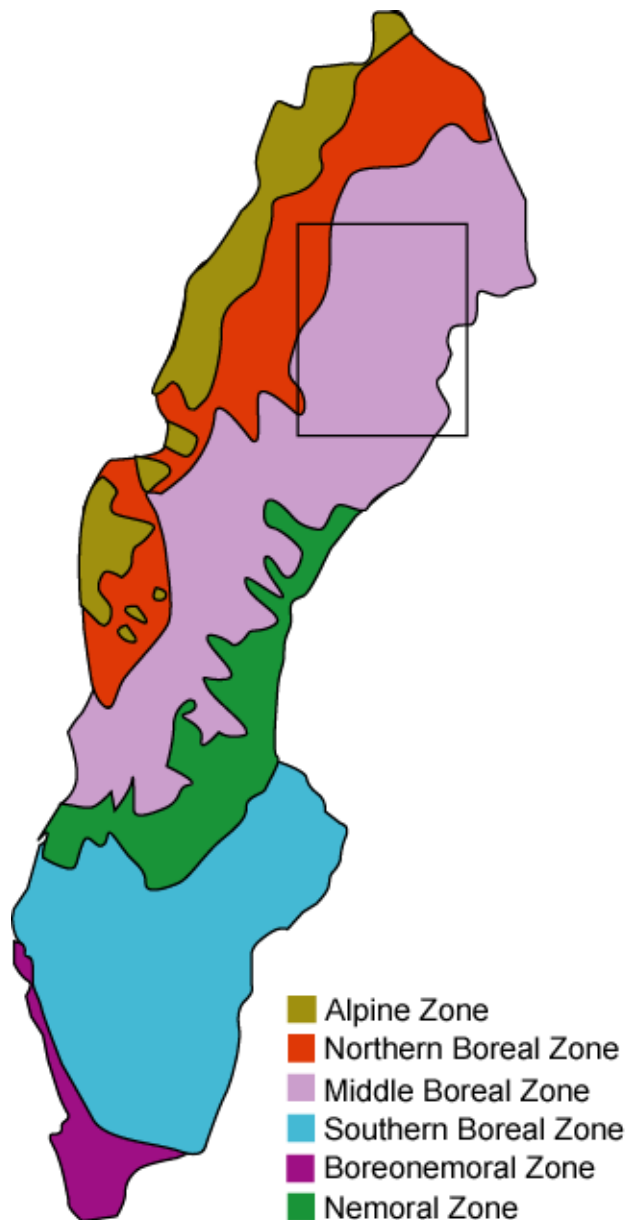
type of peatland in the south, while in the north of Sweden aapa mires dominate (Pakarinen 1995). Aapa mires are defined by (Eurola *et al.* 1995) as a mire complex (system) type whose central parts are characterised by minerotrophy and near to mire inherent influence and which may receive supplementary nutrients to its central parts — besides marginal parts and brooksides — also through snow-melt water from the surroundings (translation from Laitinen *et al.* 2007). It is estimated that 33% of peatland in Sweden has been drained in the last 200 years for forestry and agricultural purposes (Westerholm 2005, 375). The peatlands of the interior north are now being increasingly mined for peat, and vast areas of peat cutting may be seen when travelling through the area today.

Peatlands are formed as the rate of the production of organic matter becomes higher than the rate of decomposition (Charman 2002; Rydin and Jeglum 2006). Internal (autogenic) influences on peat development include geochemical, biological, physical and hydrological processes. External (allogenic) influences include geomorphology, fire, climate and human activities. The combination of these influences over time is what drives peatland formation, and identifying the variable influences of autogenic succession from allogenic forces, particularly climate, is challenging (Korhola 1995; Charman 2002, 25; Tuittila *et al.* 2007). The combination of processes influencing peat development will be discussed in more detail, considering the specific factors involved, at the individual study sites. Peatland initiation and expansion in northern Scandinavia in the Holocene period has often been concurrent with climate (e.g. Korhola 1995; Tuittila *et al.* 2007; Barnekow *et al.* 2008; Andersson and Schoning 2010; Weckström *et al.* 2010). Changes between lighter and darker peat termed 'recurrence surfaces' by Granlund (1932), are considered to be a result of changes in peat formation connected with changes in climatic conditions. The lighter bands of unhumified material may represent periods of wetter/colder conditions, while the darker, humified layers suggest drier/warmer conditions, and some support for this has been found in more recent studies in Sweden (Börjmark 2005). Human impacts can also affect peat landform development through altering the hydrology at a given site, through

activities such as deforestation, fire, drainage and other forms of land management (Charman 2002).

### **3.4 Vegetation**

Sweden can be divided into six vegetation or biotic zones (Figure 3.1). These are characterised by a multitude of factors but mainly by the type of tree that is most prevalent in each, and by aspects of their climate (Sjörs 1965; Jonasson 1996, 40). These zones include the deciduous forests in the southern nemoral zone, the coniferous-dominated forests of the northern, middle and southern boreal zones and the alpine zone, this last typified mainly by heathland vegetation. The middle and northern boreal zones characterise much of northern Sweden, extending from the coast to the mountain foothills in the west. The forested landscape is replaced by heaths and mires with increasing elevation; these eventually give way to the extreme montane region of the northwest where only a few pioneering plants, such as bryophytes and lichens survive the harsh climatic conditions (Ratcliffe 2005, 2-3).



**Figure 3.1** Vegetation map based on Jonasson (1996, 40), with the classification of vegetation zones principally determined by the dominant type of tree. The study area is indicated.

The study area falls within the boreal forest zone, and is otherwise described as the ‘Taiga’ forest, which forms a belt across parts of Scandinavia, Russia, Siberia and North America. The boreal zone is characterised by mixed forests dominated by Scots pine (*Pinus sylvestris* L.), which occurs in drier, coarse soils, prominent along the valleys and nutrient poor peatlands. Norway spruce (*Picea abies* (L.) Karst.) occurs in areas of fine-grained, richer soils, and often dominating in wetter areas

(Sjörs 1965; Kempe and von Segebaden 1990, 57-58; Niklasson and Granström 2000).

Forestry practices in much of northern Sweden have caused an increase in Scots pine in previously Norway-spruce dominated forest (Gärdenfors 2010, 89). Deciduous species, including primarily *Betula pubescens* Ehrh., *Betula pendula* Roth., *Alnus incana* (L.) and *Alnus glutinosa* (L.), *Populus tremula* (L.), *Sorbus aucuparia* (L.) and *Salix caprea* (L.), occur in varying proportions throughout the forests of northern Sweden (Niklasson and Granström 2000; Hellberg 2004; Ratcliffe 2005, 85). *A. incana* (grey alder) is the most common alder species here, pioneering along shores and river banks. It thrives in both shaded conditions as an understory shrub and also in exposed, light areas where it may grow more fruitfully, quickly establishing itself in gaps created within the forest (Sjörs 1965; Dahl 1998). *Betula pubescens* (downy birch) is the dominant species of birch in northern Sweden, where it is found mostly along the coast. The mountain birch *Betula pubescens* subsp. *czerepanovii* gradually takes over in the mountain foothills to the west, where the coniferous forest thins out (Sjörs 1965; Helmfrid and Östman 1996, 10). Birch is also an early colonist of areas affected by cutting and/or fire, and also spreads within areas of secondary forest (Niklasson and Granström 2000). *B. pendula* (silver birch) requires moisture, and does not grow well on nutrient-poor soils, while *B. pubescens* is ecologically less particular, also growing on peat bogs, in wet and compact soils (Hynynen *et al.* 2010). *Betula nana* is a low-growing species, and is frequently found dispersed across bogs in northern Sweden. *Juniperus communis* occurs within light woodlands, notably of birch, and is often absent in dense coniferous forest understoreys due to its preference for more open localities (García *et al.* 2000).

Dwarf shrubs of *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Calluna vulgaris* (L.) Hull and *Empetrum* spp., as well as feather and bog mosses, lichens and ferns commonly occur on the forest floors to differing degrees depending on forest type (Arnborg 1990; Niklasson and Granström 2000; Zackrisson *et al.* 2000; Ratcliffe 2005, 87). The dry-mesic type is dominant in the north, mostly comprising shrub vegetation (Gerell *et al.* 1996, 46-47). Shrub heath with scattered trees becomes a prominent feature of the landscape at higher elevations, giving way to increasingly

treeless tundra in the alpine zone (Ratcliffe 2005, 90, 241). Lichens, mostly of *Cladonia*, *Cetaria* and *Stereocaulon* spp., are increasingly prevalent in the north, particularly in areas of shallow soil, while moss-dominated heaths prevail on damp ground (Ekman and Iregren 1983).

The nutrient poor northern coniferous forests host vegetation including *Carex globularis* L., *Rubus chamaemorus* L., *Betula nana* L. and various mosses (Sjörs 1965, 62; Ratcliffe 2005, 18). *Vaccinium* spp. is common within drier areas of forest (Sjörs 1965, 62). A field layer consisting of *C. vulgaris*, *R. chamaemorus*, *Empetrum* spp., *Andromeda polifolia* L., *Vaccinium uliginosum* L., *Eriophorum vaginatum* L. and a base of *Sphagnum fuscum* type is most common in dwarf shrub bogs (Gerell *et al.* 1996, 52-53). Growth of trees is often inhibited within the wetlands, but where trees are able to colonise the wet surfaces and margins, they are often stunted. In the alpine zone the vegetation changes to increasingly tree-less shrub heaths with some *Betula nana* and *Empetrum*, *Salix* scrub and mires; and in the northernmost high alpine areas bryophytes and lichens form the most important components of the homogenous plant cover (Ratcliffe 2005, 2-3, 241-243).

Some 6-7% of the entire country's extensively forested area is now protected, and 3,616 nature reserves are currently established (Statistiska centralbyrån 2011). Although still spatially extensive, the structure of the forests in northern Sweden today is markedly different from how it was prior to the 19<sup>th</sup> century, when agricultural expansion began in earnest along the river valleys and the timber frontier reached the inland north (Linder and Östlund 1998; Axelsson and Östlund 2001; Östlund *et al.* 1997). Clear cutting, as well as fire protection and new planting regimes, gave rise to even-aged stands, and the diverse forest ecosystems previously characteristic of the area have dwindled. These had multi-aged and dead trees (Östlund *et al.* 1997; Linder and Östlund 1998; Axelsson and Östlund 2001; Gärdenfors 2010).

### **3.5 Climate**

The climate of northern Sweden, and of Fennoscandia as a whole, has been connected to North Atlantic oceanic and atmospheric circulation fluctuations throughout the Holocene, which have affected the direction of vegetation development (Seppä and Birks 2001). In comparison to areas at similar latitudes, Fennoscandia has a considerably warmer climate due to the influence of the Gulf Stream (Tikkanen 2005, 99). Farming takes place north of the Arctic Circle, which cuts through the area at 66°32 N, because of this phenomenon. However, pockets of cold in low-lying areas, mainly inland, can suffer from severe frost, prohibiting farming in some localities. Small lakes in the north of Sweden freeze from October until June (SMHI 2009; 2009a).

Large variations in climate are witnessed across northern Sweden, with an evident gradient from coastal to inland zones and a difference of approximately 11°C between the annual mean temperatures of the warmest and coldest areas (SMHI 2011). Snow may be present in the mountains from October through June, while in the southernmost coastal area snow may normally be found only from December to March (SMHI 2009b; 2009c). Freezing of the gulf waters begins in November, and areas along the Västerbotten and Norrbotten coasts can retain ice until May (Jonasson 1996; 35).

The wettest areas are generally the highest, with precipitation reaching a peak in the Scandes mountains (SMHI 2009d). The continental climate of the inland regions is characterised by warm and dry summers and cold winters, while the south of Sweden and small areas of the Scandes mountains and the Bothnian Coast have a much more maritime climate (Ekman and Iregren 1983; Vedin 1995, 45).

The study sites are located in areas with mean July temperatures of around 12-15°C and mean January temperatures of around -11 to -14°C (Alexandersson and Eggertsson Karlström 2001). Annual precipitation during the growing season is 300-350mm in all areas within the study except at Akkajärvi where it is slightly lower. The high levels of precipitation, and low evaporation, have encouraged the formation



of peatlands across the study area (Tikkanen 2005, 111), and the high precipitation and low evapotranspiration rates seen over much of the country are a factor contributing to the high proportion of land covered in water, reaching almost 10% (Jonasson 1996, 38).

Snow covers the ground across much of Västerbotten and southern Norrbotten from October until April (Dahlström 1995; Ratcliffe 2005, 14). The growing season at all the study sites is 120-150 days, with the first frost of the year occurring around 1<sup>st</sup> September; the last frost occurs in mid-June (Alexandersson and Eggertsson Karlström 2001).

### **3.6 Flora and fauna**

Across Fennoscandia a general pattern of declining species richness is observed in terms of flora and fauna with increasing latitude, and altitude (Angelstam and Andersson 2001; Ratcliffe 2005, 41; Eide and Aronsson 2010, 106). In the south of Sweden land use has been heavier for a longer period of time than in the north, contributing to the fact that the total number of red-listed species is markedly higher in the south (Gärdenfors 2010, 57-58). Norrbotten and Västerbotten are amongst the counties with the lowest percentage of recorded species extinctions (4.0% and 7.5% respectively) (Gärdenfors 2010, 59).

#### **3.6.1 Invertebrates**

Some 80% of faunal species in Sweden are insects, which are thought to number approximately 31,000 (Ronquist 2010, 241, 248) of which more than 4,400 are beetles (Ljungberg *et al.* 2010, 411). Since the Swedish Taxonomy Initiative launched in 2002, almost 200 species that were previously unknown in the area have been found in northern Sweden, and it is estimated that many thousands of insects remain to be discovered (Ronquist, 2010, 248). Since 2005, the number of red-listed beetles has increased by approximately 3.4% (Ljungberg *et al.* 2010).

A large number of insect species have become specialised feeders in Sweden and it is estimated that over one thousand species of Coleoptera are dependent on dead trees

for their survival in Sweden alone (Ehnström 2001). Berg and others (1994) found that old trees and logs are vital habitats for over a quarter of all threatened species of vertebrates, invertebrates, vascular plants, and cryptograms in Sweden. For invertebrates the most important habitats are old trees (35%) and snags (37%), while logs (28%) are also critical (Berg *et al.* 1994). Modern forestry may be increasing the threat of habitat loss, although Jonsell and others (1998) have found that many of the red-listed fauna in Sweden could survive in managed forests that are not ‘cleaned’ of such substrates.

In a study of beetles in Finnish and Russian Karelia, Siitonen and Martikainen (1994) found many beetles to be present in Russia that were rare or extinct in Finland. This was considered to be owing to differences in forest management in the two areas, resulting in different levels of dead wood. Forest management regimes are therefore an important issue when considering the conservation of insect species in boreal forests (Niemelä 1997; Schiegg 2000; Siitonen 2001; Grove 2002).

While many species need dead wood, others require slow-growing tree species, which are at risk as fast-growing commercially-viable trees are planted in favour of slower-growing species of conifers (Ehnström 2001). It is estimated that there are eighty coleopteran species feeding on lodgepole pine (*Pinus contorta* var. *latifolia*), a fast-growing species of tree introduced to Sweden on a significant scale only fifty years ago (Lindelöw and Björkman 2001). In contrast to the usual trend of generalist species colonising more quickly than specialists, it was found that species with a narrow food range were both quicker to colonise, as well as greater in number in lodgepole pine forests (Lindelöw and Björkman 2001).

There are several Coleoptera that are recognised as forest pests in Sweden, with *Ips typographus* (L.), *Pityogenes chalcographus* (L.) and *Tomicus piniperda* (L.) among the most prominent. These are well known for their ability to attack stressed trees, often resulting in tree mortality, and are therefore of concern to the forestry industry (Eidmann 1992; Göthlin *et al.* 2000; Lindelöw and Björkman 2001). Furthermore, it is considered that warming climate in the future may lead to increased damage by

such species (SOU 2007: 60). Although some concerns have been expressed that increasing coarse woody debris could encourage an increase in insect pests, it may be possible to strike a balance between maintaining biodiversity through leaving dying and dead wood within woodlands, and guarding against damaging outbreaks of recognised pests (Grove 2002; Ranius *et al.* 2003).

### **3.6.2            Vertebrates**

The large carnivores, notably wolf, brown bear, lynx and wolverine, once widespread in Fennoscandia, now have much more restricted ranges, mostly in Russian Lapland and the far north of Fennoscandia (Ratcliffe 2005, 289-291). Elk (*Alces alces* L.), reindeer (*Rangifer tarandus*), pine marten, mink, beavers, foxes and otters occur in the woodlands and along the rivers (Ekman and Iregren 1983; Ratcliffe 2005, 289-291). Grey seals are the most common seals found along the northern coast, with young being born in the early spring when the Gulf still holds ice (Ekman and Iregren 1983).

Reindeer have a circumpolar distribution, inhabiting boreal and tundra landscapes, and climate has a profound impact on grazing quality, movement patterns, reproduction, disease and mortality (Beach 1981, 53; Solberg *et al.* 2001; Bradley *et al.* 2005).

It is considered that all forms of reindeer and caribou can be grouped within the species *Rangifer tarandus*, with various subspecies apparent (Flint 2010, 134). Around 225,000 reindeer are currently found in Sweden, where they are herded exclusively by the Sámi (Moen and Keskitalo 2010). Around 40% of Sweden's land area is used in reindeer husbandry, constituting 51 herding districts (Moen and Keskitalo 2010).

The link between changing climate and changing resource management strategies in northern Sweden in the past has been considered by several researchers (Aronsson 1991; Broadbent 2010; Flint 2010). The dietary needs of reindeer drive the migration between different pastures throughout the year. Lichens, rich in carbohydrates, are

the main food resource during the winter (October-May), although it has been noted that lichens may be eaten throughout the year if they remain moist (Inga 2007). The reindeer dig through the snow layer to uncover the lichens, with *Cladonia* the preferred species (Inga 2007), or eat lichens growing on trees. Forested areas have a more manageable snow layer than exposed areas (Roturier and Roué 2009), and *Pinus sylvestris* forests provide ideal grazing during winter (Inga 2007).

Various factors affect the grazing quality and therefore the patterns of reindeer movement - snow cover can be particularly problematic (Roturier and Roué 2009). Indeed, there are many variables that contribute towards high quality pasture - including vegetation composition and weather (Kitti *et al.* 2006) - and these can fluctuate in accordance with changing climate and land management. If winter pasture conditions are poor, this can affect the herds and their productivity drastically (White 1983).

Late summer and autumn see the consumption of mushrooms, an important source of protein (Inga 2007). In the summer months reindeer feed mainly in wetland areas where grasses, shrubs and herbs provide their main food sources (Kitti *et al.* 2006; Inga 2007). In summer, when insect harassment is at its peak, reindeer are forced to move regularly, affecting their feeding (Iver *et al.* 2002).

The elk similarly has a seasonal diet, foraging herbs and leaves in the summer, and twigs in the winter (Ekman and Iregren 1983).

Northern Sweden's population of breeding birds is predominantly comprised of migrants seeking the long daylight hours of the summer months. Some birds remain year-round, including grouse and corvids. The timing of ice-melt in bogs, lakes and rivers determines the timing of the return of many birds to these habitats after their winter migrations. Old growth forest is an important habitat for the bird fauna of northern Sweden, hosting a rich variety of bird life, and the availability of old and dead wood here is vital for the survival of many species, particularly hole-nesters (Ratcliffe 2005, 95).

An investigation of osteological material from pre-historic habitation sites across northern Sweden by Ekman and Iregren (1983) found that elk, beaver and reindeer were the most commonly exploited mammals, while the remains of gallinaceous birds were amongst the most numerous represented. Pike, bream and perch were significant amongst the fish bone material, with pike being a widespread species in Sweden, and a species which can be caught almost year round (Ekman and Iregren 1983). Ermine, red squirrels, red foxes and wolverine were often hunted by Sámi groups in the north (Josefsson *et al.* 2010a). Furs were used by the Sámi for trade, and to pay taxes in the 1500s, but during the 17<sup>th</sup> century the fur trade suffered a major blow as resources became increasingly depleted (Lundmark 1982; 2007).

## 4 Environmental History of Northern Sweden

Having discussed the modern ecological setting of the research area in Chapter 3, aspects of the environmental history of northern Sweden will be addressed here. In studying the past environment, as is the focus of this research, it is necessary to have an understanding of the processes at play on this landscape, and the ways in which these have affected environmental changes over time. Millions of years of natural landscape change, and thousands of years of human impacts have shaped the landscape of Sweden as we know it today, and many of the processes which have driven these changes are ongoing.

### 4.1 *Natural environmental change*

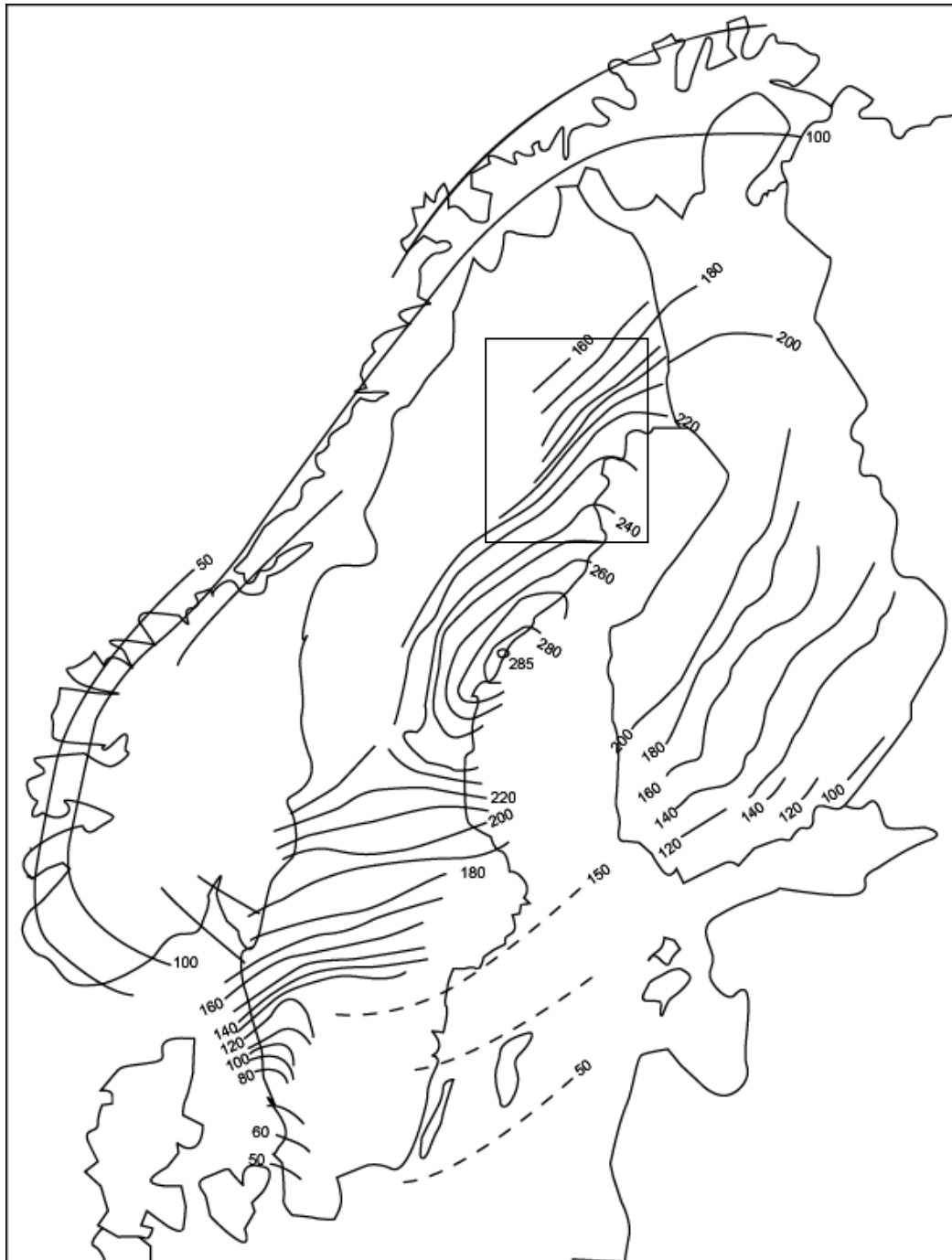
The Baltic Shield, the bedrock geological formation of which Sweden is part, is the product of many Precambrian orogenies. The study area forms a component of the Svecofennian belt, one of the three main geological provinces of the Precambrian domain, which covers most of northern Sweden (Lidmar-Bergström and Näslund 2005, 4-5). The bedrock is dominated here by Archaean gneisses and granites, with elements of acid volcanic rock (Jonasson 1996, 26).

The Scandes mountains, at the border between Sweden and Norway, reach heights of 2500m asl, and were formed by Tertiary uplift (Lidmar-Bergström and Näslund 2005, 5). The later effects of processes, such as weathering and fluvial and glacial erosion, have shaped the mountains as we know them today (Jonasson 1996, 21).

The sculpted landscape of moraines, drumlins and eskers is a visible product of the advances and retreats of glaciers; fluvio-glacial features are found in many parts of the north, often indicating the direction of ice movement (Seppälä 2005). Deglaciation left much of southern Scandinavia ice free by 13,500 BP and much of Finland by 10,000 BP, while inland Sweden remained locked in ice until more than 1000 years later (Bergman *et al.* 2004). Deglaciation of the Norrbotten coast occurred by 10,500 BP (Lindén *et al.* 2006), and in coastal Västerbotten during the

period 10,600-10,000 BP (Berglund 2011). The ice receded inland, to a centre around the mountains in the north-west (Fredén 1994, 131).

The warming climate and consequent retreat of the ice led to rapid isostatic uplift. The rate of uplift differed across regions. At present the rate of uplift in parts of coastal Västerbotten reaches 9mm per year and the highest shoreline is 260m asl, having slowed since the Early Holocene maximum uplift (Eronen 2005, 22; Lindén *et al.* 2006; Berglund 2011). Non-uniform isostatic uplift has resulted through time in an east-west land tilting in much of the interior, altering river hydraulics, changing the drainage of lakes, and causing shoreline displacement (Påsse 1998; Bergman *et al.* 2003; Hörnberg *et al.* 2005; Eronen 2005, 32; Lindén *et al.* 2006; Berglund 2011). Raised shorelines are further products of uplift, and the highest shorelines are presented in Figure 4.1. In northern Sweden periods of stability, when isostasy and eustasy are in equilibrium, have resulted in accumulations of Stone Age archaeological finds and some ancient sites, once at the coastal edge, have risen over 120m asl as a result of land uplift (Broadbent 2010, 47). Continuing land uplift creates new lakes from former sea bays along the changing coastline of Northern Sweden (Jonasson 1996, 38). Uplift is a continuing, but slowing process (Eronen 2005, 32).



**Figure 4.1** The altitude of the highest shoreline in Scandinavia (from Eronen 2005, 23). The study area is indicated.

Changes to the Baltic basin were marked as the ice retreated. Saline water entered the Baltic Sea basin during the Yoldia Sea phase beginning 10300 BP, and the subsequent uplift of the landmass closed off the ocean connection at the Närke strait c. 9500 BP (Eronen 2005, 24). The freshwater Ancylus Lake was then formed as



water levels in the Basin steadily increased. Approximately 300 years later drainage of this basin through a newly formed outlet led to a lowering of the water levels, and the inflow of water from the sea created increasingly brackish conditions marking the beginning of the Littorina Sea stage from around 7500 BP (Eronen 2005, 24-26). Since this time sea levels have lowered, salinity has declined and the Baltic Sea as it is known today was formed (Björk 1995; Eronen 2005, 25-26).

As ice retreat slowed to a stop it deposited ice and sediment in the valleys, resulting in the distinctive positions of the largest lakes in northern Sweden which are centred on a north-south strip along the halt line (Ekman and Iregren 1983). Most lakes in northern Sweden are of glacial origin (Seppälä 2005, 142).

The immigration of flora and insects followed rapidly in the wake of the downwasting of the ice sheet (Jonasson 1996, 38). A southern connection to the continental landmass provided one of the main routes of immigration for flora and fauna after the last ice retreat, and another route from the east was also important for the colonisation by vegetation of northern Sweden at this time (Berglund *et al.* 1996b, 14).

The history of vegetation development in Sweden varies greatly from area to area, and is a product of differences in climate, topography, soil and hydrography (Jonasson 1996, 40). Latitude and altitude are also important in determining biodiversity (Gaston and Williams 1996; Angelstam and Andersson 2001). Although the number of palaeoecological studies of the northern Swedish postglacial landscape has increased substantially in the 21<sup>st</sup> century, climatic changes and the patterns of immigration by flora and fauna are currently understood on the basis of studies conducted primarily along the coastal zone and from high altitude sites in the far north. The variable degree of precision of the different dating methods employed across studies (e.g. Korhola *et al.* 2000; Rosén *et al.* 2001; Seppä and Birks 2001; Snowball *et al.* 2002) adds to the difficulties of developing secure and cross-study applicable chronologies, and this has been a constraint on the development of regional palaeoclimate models.

## 4.2 Vegetation development and climate

Vegetation development and climate through the Holocene period in northern Sweden will be discussed. Through this discussion the contribution of different proxies will be highlighted, and some of their limitations addressed. As the response of organisms to climate change differs, and the palaeoenvironmental record reflects different degrees of environmental change (e.g. local or regional) depending on the proxy used, the following discussion will consider a range of proxy data in order to build a picture of natural vegetation and climate change during the Holocene in northern Sweden. Areas of study regarding past vegetation development and climate change where the data is thin, or controversial, will be considered.

Current understanding of the vegetation development of northern Sweden is based primarily on pollen studies and macrofossil evidence. Such studies show that, in much of northern Sweden, the initial tundra vegetation developing in the deglaciated landscape was quickly followed by the establishment of birch and then the appearance of pine and alder (Sonesson 1974; Berglund *et al.* 1996a; Barnekow 1999; Barnekow 2000; Barnekow *et al.* 2008; Seppä and Birks 2001; Snowball *et al.* 2002; Hörnberg *et al.* 2005)(Figure 5.1). The recent finding of a vegetated landscape c 8700 BP (uncal), with tundra vegetation and a rapid expansion of tree species, primarily *Betula* with *Pinus*, has been observed in the pollen record by Hörnberg and others (2005) in the Arjeplog region. Tundra and steppe vegetation, with pioneer and shade intolerant species and low pollen accumulation rates of tree species, similarly typified the landscape around Barnekow and others (2008) study site at Lake Svartkälstjärn in Västerbotten as the ice retreated. Trees gradually increased in importance, succeeded by scattered pine and birch, with dominance of deciduous species from c. 7000 BP. At the study sites of Sarsjön and Frängsjön, Snowball and others (2002) similarly see birch colonise in the area c. 4500 BP followed by pine expansion a few hundred years later. Engelmark's (1996) investigation of sites along a transect stretching from the coast to inland Västerbotten found *Betula* was prominent at sites closer to the coast in the Early Holocene, compared to the *Pinus-Betula* forests inland. From the period around 5500-6000 BP (uncal), the inland sites studied by Engelmark (1996) in Västerbotten similarly display high proportions of

*Betula*. *Alnus* shows differing values across the sites investigated so far in Västerbotten, principally occupying the wetter areas (Englemark 1996; Snowball *et al.* 2002; Barnekow *et al.* 2008).

Evaluating the extent of thermophilous plant species occurring in northern Sweden during the Early-Mid-Holocene remains problematic, with careful consideration of the sample context, and detailed information using pollen accumulation rate (PAR) values often needed to allow discrimination between local populations and long-distance transport of pollen. Snowball and others (2002) have noted increased *Quercus* and *Corylus* in the pollen and macrofossil record *c.* 7700 BP in Västerbotten, considered alongside other proxy indicators as a response to warmer temperatures. A consideration of the frequency and PAR values, allows Barnekow and others (2008) to distinguish between occurrences of *Quercus*, *Ulmus* and *Tilia* in the pollen record occurring most likely as a result of long distance transport prior to *c.* 7000 BP, from the local populations present after this time.

Using macrofossil evidence, which tends to be a reliable reflection of local vegetation due to limited dispersal distances (Birks and Birks 2001), Kullman (1998a, 1998b) has demonstrated that the Scandes mountains hosted tree species that presently have much lower distributional limits, including *Tilia*, from 8000 BP. The presence of warm-loving species during the Early Holocene demonstrates summer temperatures that were warmer than at present in the southern Swedish Scandes at this time (Kullman 1998a, 1998b). In the northern Swedish Scandes, the finding of macrofossil evidence of *Pinus sylvestris*, *Betula pubescens* spp. *tortuosa* and *Alnus incana* at elevations above the modern tree-limits also indicates that Early Holocene temperatures were significantly higher than at the present. It is estimated that by 8500 BP, summers were approximately 2.4°C warmer than present, within a continental climatic regime (Kullman 1999). Macrofossil evidence provides an important component in developing palaeovegetation and climate models, as it is able to resolve uncertainties that may be present in the pollen evidence. Indeed, this point has been demonstrated in the discrepancies seen in the study of Late Glacial palaeoenvironmental data from Norway in which macrofossil evidence provided a different interpretation of the local vegetation than that gained from the pollen

record, which had been heavily influenced by long-distance pollen (Birks and Birks 2001).

Climatic inferences from the Holocene period are primarily based on diatom, chironomid and pollen evidence, often found in lake cores. Diatoms have become increasingly employed in palaeoclimatic reconstructions, having shown consistent synchronicity with present day temperatures (e.g. Rosen *et al.* 2003). Climatic reconstructions based on chironomids have been compared with other proxy data, showing consistency throughout the Late Glacial, however the shorter temperature changes known from the Holocene period may not be strong enough to override the influence of local conditions, resulting in variable reconstructions over this period across proxies (Velle *et al.* 2010).

Pollen analysis has been commonly used to infer climate changes since the 1980s (Birks 1981), although few validation tests have been carried out (Seppä *et al.* 2004). A recent study by Salonen and others (2012) which considered the response of pollen types to different climatic parameters indicates the significant influence of parameters other than summer temperature on specific taxa, suggesting caution in determining summer temperature reconstructions from pollen analysis, and difficulty in reconstructing secondary parameters (e.g. winter temperatures). Other methodological difficulties were identified in the study, such as the incorporation of long-distance pollen into assessed samples, affecting the reconstructed temperatures. Nevertheless, Seppä and others (2004) tested the method using a modern pollen-climate calibration set, corroborating the use of pollen analysis in climatic reconstructions on a centennial to millennial time scale and in detecting drastic short-term climatic shifts.

Rosén and others (2001) provide a comprehensive multiproxy study including diatoms, chironomid, pollen and near-infrared spectroscopy from a mountain lake in northern Sweden. Some inconsistencies are observed between proxies, as the timelag response to climate varies across proxies, and each is influenced by a variety of factors (e.g. summer water temperatures, length of growing season, vegetation cover)

to varying extents. Nonetheless, general patterns are witnessed across the data types. The Early Holocene temperatures, which Rosén and others (2001) consider with some caution due to the lack of modern analogues, were comparable to today. However, short term fluctuations between both colder and warmer temperatures were notable, and a general decrease of temperatures during the latter part of the 9<sup>th</sup> millennium BP. A warm period began abruptly c. 7300 BP (Rosén *et al.* 2001). Other pollen and diatom records from northern Scandinavia similarly show that low, but steadily increasing, temperatures through the Early Holocene progressed to a warm period from c. 8<sup>th</sup> millennium BP (Korhola *et al.* 2000; Seppä and Birks 2001). The expansion of pine in northern Sweden around this time may be equated with the observed drier and warmer conditions prevailing in Fennoscandia (Sonesson 1974; Barnekow 2000; Seppä and Hammarlund 2000)(Figure 5.1).

Snowball and others (2010) conclude that varved lake sediments from Swedish sites can be ‘anchored’ to the radiocarbon calibration curve from tree-ring data, and synchronised with Greenland ice-core records through radiocarbon wiggle matching. A comparison of the proxies can be undertaken, allowing synchronisation of time-scales across proxies with respect to the severe climatic change of the 8.2 kyr cold event. Snowball and others (2002) find evidence of a significant climatic change occurring c. 8000-7700 BP. This is witnessed in the fall in the total pollen influx, a pattern that may reflect lowering temperatures, alongside evidence for the heightened frequency of frost reflected in increased mineral matter accumulation. This is suggested to be related to the 8.2 kyr BP cooling event. This cooling event has similarly been identified in a study by Korhola and others (2000), where a diatom based calibration model indicates a period of colder summer temperatures centring around this time. Hicks (2006) suggests that the decline in *Pinus* pollen found in many Scandinavian pollen diagrams 8200 BP could be the result of sudden cold temperatures inhibiting flowering. This cold event has also been linked with decreased frequency of fires in southern Swedish forests (Greisman and Gaillard 2009).

In western Finland, evidence of dry conditions with lowered lake levels from 8000-4000 BP has been observed in the diatom and cladoceran evidence which is

considered to be driven by climate (Hyvärinen and Alhonen 1994). After this period humidity may have increased. Almquist-Jacobson (1995) shows a similar trend of lowering lake levels from 8000 BP in central Sweden, based on sedimentologic and macrofossil analyses of sediment cores. Around Lake Torneträsk, Barnekow (2000) found evidence in the palaeoecological record of lowered lake levels c. 6300 BP during the warm and dry conditions of this period, followed by a rise in lake-levels by 4500 BP.

The Late Holocene is generally characterised by decreasing temperatures, witnessed by glacial readvances (Nesje 2009) and retreating tree lines (Reuss *et al.* 2010) particularly over the last few thousand years (Figure 5.1). This cooling, coupled with increased precipitation, has been linked with paludification and peatland expansion (Seppä and Birks 2001; Barnekow *et al.* 2008). The colder, wetter conditions c. 3200 BP favoured the expansion of spruce in some areas (Barnekow *et al.* 2008) Figure 5.1. Studies of lake level changes in northern and central Scandinavia indicate that the period from around 4000 BP was generally characterised by higher lake levels, although localised fluctuations are seen (Hyvärinen and Alhonen 1994; Almquist-Jacobson 1995; Barnekow 2000). At Mesolithic settlement sites around Lundfors in Västerbotten, the increased salinity in the Littorina Sea which favoured marine life occurred alongside climatic amelioration, conditions which may have encouraged settlement of the Bothnian coast around 3500 BC (Engelmark 1979).

Evidence of Late Holocene climate change owes much to the development of dendrochronology. An understanding of the complex influences governing tree-ring growth has been necessary in the development of this sub-discipline, and it is recognised that as well as summer temperatures, the growth of tree rings is governed by aspects such as precipitation, timing and length of growing seasons, water and nutrient uptake, CO<sub>2</sub> and UV radiation (Briffa 2000). However, particularly in northern Scandinavia where many trees are growing close to their ecological limits, summer temperature and tree-ring width are considered to be in close relationship (Grudd *et al.* 2002). The emerging differences between tree ring data and modern temperature data have been suggested to be either a response to changing

environmental conditions, or a result of the standardisation process (Grudd 2008). A recent study by Gunnarson and others (2012) suggests that past land use by Sámi groups in northern Sweden could have affected tree-ring growth, and therefore the inferred climate signal from the growth-ring patterns may be erroneous. The possibility of such localised impacts from human groups highlights the need for multiple samples from across sites, and inter-study comparisons, to achieve the most accurate climatic reconstructions. An understanding of the ecological and cultural history of an area, drawing on a range of different lines of evidence where possible, will enable the development of increasingly subtle and valid palaeoclimatic models.

Dendrochronology remains central to understanding climatic changes in northern Scandinavia, based on high resolution data on an annual scale, with the most extensive tree-ring chronology for northern Sweden dating back over 7400 years, based on data from Torneträsk (Grudd *et al.* 2002). The ADVANCE-10K project has worked towards building a high resolution chronology of climate change over the last 10,000 years using tree-ring data from across Eurasia (Briffa and Matthews 2002). This is valuable in providing a context of broad scale climate change against which evidence for environmental changes found in this research can be considered.

With regard to the Late Holocene, tree-ring data from northern Sweden has revealed several major climatic events during this period (Figure 5.1). These include the period between 600 and 1 BC (Grudd *et al.* 2002), at the juncture of the Bronze and Iron Ages, a time when Engelmark (1976) has noted changes in human activity along the Västerbotten coast. The tree ring data from Finnish Lapland and from Torneträsk in northern Sweden, show evidence of a severe climatic change c. 330 BC, with increased wetness and colder conditions prevailing, followed by warming in the early centuries AD (Eronen *et al.* 2002; Grudd *et al.* 2002). This warmer period is superseded by colder temperatures during the ‘Dark Ages’, from c. 500-900 AD (Grudd *et al.* 2002).

In the last few hundred years, two marked climatic events are thought to have occurred across Europe and the North Atlantic: the Medieval Warm Period and the

Little Ice Age (Figure 5.1). These appear to have differed in timing and extent across much of the affected area, as demonstrated in the discussion below. Furthermore, the Little Ice Age does not appear to have been a period of continual colder temperatures, but of highly variable climate, as will be discussed.

Warm summer temperatures centring around 1000 AD are seen in the Torneträsk tree-ring data, corresponding with the Medieval Warm Period (Grudd 2008) although no such signal is seen in the Finnish tree-ring record (Eronen *et al.* 2002). In the diatom evidence studied by Korhola and others (2000) in Finnish Lapland, warming is recognised during the period c. 900-1300 AD, while a cold spell of 300 years is observed in the diatom evidence from c. 1550 AD. Bjune and others (2009) find indications of the coldest periods centring around 1400-1500 AD, and also 1800-1900 AD, but with no clear indication of warmer temperatures during the Medieval Warm Period in the pollen record from sites across northern Scandinavia. At Lake Sjuodijaure in northern Sweden, Rosén and others (2001) found the diatom *Fragilaria pinnata* var. *pinnata*, which occurs in high altitude lakes, in samples from c. 400-50 BP. Increasing numbers of the chironomid *Corynocera oliveri* type which is indicative of colder conditions are found c. 800-30 BP (Rosén *et al.* 2001). At Lappmyran, Västerbotten, a shift in the composition of surface mosses, thought to indicate wetter conditions, has been identified as coinciding with the Little Ice Age. The corresponding pollen data do not reveal a signal of climate change during this time (van der Linden *et al.* 2008). Furthermore, documentary evidence records severe crop failure during the years from 1601-3 AD in northern Sweden associated with a downturn in temperatures (Utterström 1955).

Bradshaw and Zachrisson (1990) demonstrate the key role of climatic factors in determining fire events in northern Swedish forests, noting the Little Ice Age lull, where climatic conditions effectively quelled outbreaks of fire. They suggest this period of cold and wet c. 700-300 years ago encouraged the establishment of *Picea*, with the previous *Betula* forest unable to withstand such conditions. This demonstrates that natural climatic factors have also played an important role in shaping the vegetation of the boreal forest during the Late Holocene in some areas.



In contrast, in the Vindelälven valley Zackrisson (1977) has demonstrated the increased frequency of fire in the last 600 years, with no Little Ice Age lull apparent. This suggests that during the Late Holocene, as human impact became a more significant factor, fire regimes became locally variable.

During the Late Holocene natural vegetation and climatic changes become increasingly intertwined with human disturbances in the landscape (Figure 5.1), and it is apparent that human intervention is driving these localised differences between sites. Over the last few thousand years the forest vegetation at sites studied in Västerbotten show variable proportions of tree species, although the general trend is a move towards coniferous-dominated forest in most of the studied areas (Engelmark 1996; Barnekow *et al.* 2008).

In summary, a general pattern of Holocene vegetation development and climate change in northern Scandinavia has been developed (Figure 5.1), and studies are increasingly taking a multi-proxy approach, producing interpretations based on knowledge of not only the regional, but also the localised, influences at play. Furthermore, as studies concerned with analysing the source areas of different proxies and their sensitivity to different variables are being increasingly employed, more accurate and precise interpretations are emerging. The long records presented in some studies offer useful time-depth of information, although more fine-tuned climatic variations can only be drawn from high resolution records.

Nevertheless, current understanding of past vegetation and climate change in the northern interior of Sweden is based primarily on pollen evidence, and this needs to be substantiated by other proxies, particularly those which can provide more straightforward local interpretations, such as macrofossil and insect fossil evidence. Particularly for the Late Holocene period there is a need to refine the signal of local natural environmental change to enable an assessment of the variable role of human impacts in the landscape, which should not be underestimated as a variable affecting the proxy evidence. In the following chapter human activity in northern Sweden, based on both the archaeological and palaeoecological records, will be discussed,

exploring how human groups have utilised and impacted upon the landscape of northern Sweden over time. This will provide a contextual background for this research and highlight current understandings and areas of limited study.

Date (BP)	Period	Epoch	Climatic period	Archaeological period	
500	Quaternary	Holocene (Post Glacial)	Subatlantic	Post Medieval	
				Medieval	
1000				Late Iron Age	
2000				Early Iron Age	
3000			Subboreal	Bronze Age	
4000				Neolithic	
5000		Pleistocene (Late Glacial)	Atlantic		
6000			Mesolithic		
7000				Boreal	
8000					
9000				Younger Dryas	
10000					
11000				Allerød	
12000				OD	
				Bölling	
13000				Oldest Dryas	
14000	Weichselian glaciation				

**Figure 4.2** The timing of events/periods mentioned in the text. Climatic stages based on the Blytt-Sernander sequence, are taken from the National Atlas of Sweden (Jonasson 1996, 22), and the archaeological periods from Broadbent (2010, 30).

## 5 Cultural Setting

### 5.1 *The archaeological evidence*

Environmental parameters were important in influencing the way of life of the occupants of the earliest human groups in northern Sweden. Changing seasonal resources were an important influence in determining the timing and length of settlement and exploitation of early human groups in northern Sweden. Natural climatic and vegetational changes also imposed constraints, and adaptations were necessary in response to this, such as increased settlement mobility (cf. Krupnik 1993; Broadbent 2010).

That people came to inhabit northern Sweden over 8000 years ago is witnessed in the archaeological remains found across the area, which have been radiocarbon dated to this period (Bergman *et al.* 2003, 2004). However, investigated Mesolithic archaeological sites with radiocarbon dates remain few in number (Bergman *et al.* 2004) and current understanding of early colonisation patterns and the nature of settlement and resource use remains limited. This has partly been a consequence of difficulties in locating early settlements in a landscape that has been significantly altered by the effects of isostatic uplift, meaning that sites are no longer located as close to ancient shorelines as they were in prehistoric times (Bergman *et al.* 2004; Hörnberg *et al.* 2005). The possibility of modelling ancient shorelines may change this, enabling sites to be more easily detected in the landscape (e.g. Hörnberg *et al.* 2005).

The Sijdda system of social organisation of historic Sámi groups is thought to have typified prehistoric settlement, reflected in the arrangement of dwellings found in archaeological sites across the interior north (Mulk 1994; Hedman 2003). These small, flexible groups could move around within a demarcated area, enabling exploitation of different resources throughout the year without over-exploitation, both when carried out in relation to either hunter-gathering and/or reindeer herding (Broadbent 2010, 160).

The settlement model presented by Forsberg (1985) for the Lule River Valley is founded on the idea that a seasonal settlement pattern typified the hunting economies of the prehistoric era. The instability of the postglacial environment forced groups to adapt to the constantly changing conditions, moving between several exploitation sites in the forest and into the mountain zones. In the early/middle Neolithic the pattern consisted of a main residential settlement founded in the forest with associated outlying exploitation camps, some reaching into the mountain foothills. By around 1500 BC two seasonal camp bases were in use, one in the mountains and one in the forest, each with associated exploitation camps and a transitory camp between (Forsberg 1985). Bergman (1995), who studied the archaeological sites and material from sites in the far interior region around Arjeplog, similarly concluded that exploitation of the forest and mountain zones occurred on a seasonal basis in the Late Neolithic, and that more permanent residential bases were a product of the Early Iron Age in that environment. The forest sites were used primarily in winter, the mountain sites in summer, with possible larger aggregation camps used for a short time during part of the year (Bergman 1995). The settlements were analysed in terms of their structure and size, and the type, diversity, extent and spatial distribution of artefacts. These differences were taken to relate to differences in the use of sites, which could then be classified according to their function and periodicity of use. Although these studies are significant in that they are the first to address settlement patterns in the inland north, they are nonetheless based on limited finds for some periods, and lack chronological control, making assumptions about the restricted data that require further corroboration. Palaeoecological investigations may provide more fine-grained information regarding the nature of exploitation and periodicity of use of early settlements. Future investigations will need to utilise extensive radiocarbon dating in order to provide a clear chronological framework within which the data can be understood.

Broadbent's (2010) integrated model of northern Swedish settlement suggests that the two key spheres, the coast and the inland zone, were not isolated from each other, but part of a much broader complex subsistence strategy employed by Sámi groups

in the face of changing climatic and social circumstances. This is based on the analysis of archaeological features, macrofossils, charcoal, osteological remains and extensive radiocarbon dating at sites along coastal Västerbotten. His endorsement of the theory of ‘punctuated sedentism’ puts forward the idea that populations on the coast and inland practiced a form of sustainable management of their resources by moving between areas, exploiting peaks and avoiding dips in local natural resources; and that they did so recurrently from Mesolithic to Medieval times. Seal hunting on the coast may have been carried out during times of plenty, when particularly warm and wet conditions encouraged seals to enter the archipelagos. During phases of abandonment of sites along the coast that could last for several decades, the resources of the interior were alternatively exploited, resulting in a bipolar system whereby the interior and coast were inextricably linked. Although localised movements between sites has long been accepted as a factor of Sámi exploitation practices, Broadbent (2010) is here proposing a regional perspective of longer-term adaptive strategies for the first time. Beginning with extensive surveys and excavations of sites over a 500 km transect of the north Bothnian coast, Broadbent (2010) considers the resulting archaeological data alongside soil-chemical, animal osteological, macrofossil and charcoal analyses, as well as considering place-name distributions and tax records. This thorough, interdisciplinary approach makes Broadbent’s theory convincing, and this broader scale model may well prove to be more consistent with the adaptable and flexible movement of indigenous populations whose subsistence is based on seasonal exploitation of available resources.

A shift in economy, with domesticated reindeer now being kept for use as decoys and for transport, occurred around the Late Iron Age in northern Sweden (Aronsson 1991; Hedman 2003). These recent studies are adopting a holistic approach, with a focus on the broader social, political and environmental circumstances in which reindeer domestication and later pastoral herding was developed (Figure 5.1). It appears that although domestication on a small scale was initiated from this early date, large-scale reindeer pastoral economies are considered to have emerged only in the last few hundred years in northern Sweden (Aronsson 1991).

The use of ethnographic studies of reindeer herding groups in northern Scandinavia from the late 19<sup>th</sup> and 20<sup>th</sup> century (e.g. Tanner 1929; Tegengren 1952; Manker 1968; Ruong 1944, 1945) refers only to the extensive system of reindeer herding, which involved larger herds used mainly for meat production (Aronsson 1991; Lundmark 2007), and not to the activities of the earlier herders. Literary evidence referring to the period of earlier, intensive herding, includes the written account of Olaus Magnus (1555) which provides information about the economic importance of reindeer, noting the practice of reindeer milking in the 16<sup>th</sup> century. He discusses how reindeer would be kept in pens and describes the use of reindeer milk, hide, sinew, bone, antler, hooves, hair and meat, and provides evidence regarding the use of reindeer as pack animals. Schefferus (1674) further discusses the keeping of large stocks of reindeer alongside the exploitation of a wide range of resources deploying a range of techniques including hunting, trapping, fishing and gathering, the emphasis on which differed between the mountain and forest groups. In a 9<sup>th</sup> century account given to King Alfred, the Norwegian chief Ottar discusses the Sámi as owners of domestic reindeer (Meriot 1984). The literary evidence provides evidence that by at least the 9<sup>th</sup> century domesticated reindeer were being kept, and by the 16/17<sup>th</sup> century in some areas of northern Sweden large herds of reindeer were kept within an economy including various other methods of resource exploitation.

Along the coast and river valleys of Västerbotten and Norrbotten the introduction of settled farming accelerated from the 13<sup>th</sup> century (Broadbent 2010). Prior to this, during the Iron Age, the northern extent of settlement by Germanic settlers was in Ångermanland, a historical province adjoining the southern border of the modern county of Västerbotten, while Finnish settlers inhabited the coast as far south as the Skellefte river (Broadbent 2010, 18). In the Tornio Valley the history of this colonisation has been studied in detail, by supplementing the archaeological record with written source material and palaeoecological evidence (Sundström *et al.* 1981). This multi-disciplinary study has revealed a complex settlement history of successive waves of migration from 1000-1600 AD by Scandinavians, Karelians and Savolaxians, gradually pushing the indigenous Sámi from the coastal areas.

Broadbent (2010) suggests that during the time of settler expansion in northern Sweden the Sámi faced the choice of settling on the coast, assimilating with the sedentary European population, or employing new economic strategies in the inland region. He suggests that it was this set of circumstances which gave rise to reindeer pastoralism proper - large scale herding within a nomadic economy.

Finnish settlers brought with them a system using 'slash and burn' (*Svedjebruk*), allowing settlement in areas that otherwise were not naturally cultivatable (Montelius 1960). Slash and burn is a method employed in crop production known to have been practiced by farming communities in Sweden into the modern period (Segerström and Emanuelsson 2002; Östlund *et al.* 1997). Due to the differences in overall resource use between the Sámi and the new arrivals, it was thought that there would be little conflict between the incoming farmers and the indigenous Sámi groups (Hultblad 1968). However records of disputes over the rights to fishing waters, and to other land used by the Sámi for hunting, suggest otherwise (Hultblad 1968).

Hultblad (1968, 437), suggests that from at least the 16<sup>th</sup> century the Sámi in Sweden gathered at central points within their devised territories during the winter, as evidenced in tax rolls and old maps dating from this time. Archaeological investigations at these Sámi winter villages indicate a long history of use, with charcoal from hearths dating as far back as the late 12<sup>th</sup> century (Liedgren 1997; Rydström 2009). Many of the church and market places later established by the State during the settlement expansion in 17<sup>th</sup> century are thought to have been developed in areas formerly used as Sámi winter villages (Bergling 1964, 147-150). The setting up of church and market places would have had a two-fold benefit for the Swedish state: allowing them a tighter grip on trade and on tax collection, as well as enlivening their efforts to Christianise the Sámi, thereby consolidating the north under Swedish state control (Söderholm 1973).

The archaeological evidence for human occupation in the northern interior of Sweden provides a firm basis on which to begin to understand settlement patterns and movements in the landscape in connection with broader social, political and

environmental changes (Figure 5.1). Nevertheless there is an apparent need to supplement the archaeological evidence with palaeoecological studies in order to facilitate a deeper understanding of human-environment relationships in northern Sweden during the Holocene.

## **5.2 Human Impacts in the Palaeoecological Record**

### **5.2.1 Early evidence for human impacts –hunters and herders**

A consideration of the palaeoecological evidence from sites of Sámi activity in northern Scandinavia highlights the contribution of such studies in this area of research, and consider some of the difficulties faced in studying periodic human impacts in the boreal forest zone.

With the aim of concluding whether different types of human activity can be inferred confidently from pollen assemblages, Räsänen (2001) studied the modern pollen from a range of natural and human-affected sites in northern Fennoscandia. She found that grazed and trampled sites could not be separated on the basis of the pollen spectra recovered, but that settled and trampled sites were distinguishable from each other. Human settlement increased species diversity in its vicinity, including a suite of pollen taxa associated with disturbed ground perhaps as a result of human activity, including *Rumex acetosa/acetosella* and *Solidago* type Cyperaceae. These taxa flourished at trampled sites. However, the signal in the pollen record from settled and trampled sites, showing changes in vegetation as a result of fertilisation, may only be able to be confidently assigned to settlement or reindeer activity based on the associated archaeological remains. This highlights the difficulties faced when archaeological remains are not currently visible in the landscape, which may mean that linking the changes in vegetation recognised in the pollen to specific types of subsistence activity, is not possible.

Although pollen research has the potential to deliver clear evidence regarding human activity and impacts in the past, the signal often becomes more ambiguous when sites



in the boreal forests of the north of Europe are considered (Hicks and Birks 1996). The signal in such environments may be dampened by the low number of indicator pollen grains present in many areas, and the very nature of human activity – often short-term seasonal use by small numbers of people- leaves a relatively light imprint upon the landscape to be detected through the pollen evidence. However, significant, often abrupt changes in environment, and association with archaeological evidence suggesting human occupation, can provide clear signals of human impacts in some instances. Understanding the finer details of traditional Sámi activity in the boreal forest zone within the hunter-herder economy, such as the spatial extent of impacts and the duration of site use, remains limited.

Pollen evidence from the oldest securely dated dwelling sites in northern Sweden (Dumpokjauratj and Ipmetisjauratj) in the Arjeplog region, initially reflects natural vegetation development with no clear evidence of human influence (Hörnberg *et al.* 2005). At Dumpokjauratj the decline in the forest cover of pine and birch occurring c. 8400 BP (uncal) , and an increase in Poaceae and *Hippophaë* alongside plants and herbs indicative of more open conditions, may be considered as indications of localised human impacts (Hörnberg *et al.* 2005), although this should be regarded with caution due to the subtlety of the signal. Similarly at Ipmetisjauratj, changes including a reduction in woodland and the extension of a more diverse, herb-rich spectra witnessed in the pollen record suggests opening of the landscape and possible exploitation of the surrounding forest at an early date. After the settlement phase at Dumpokjauratj, indications of continued use are much more subtle and are perhaps ascribable to natural rather than human induced changes (Hörnberg *et al.* 2005).

In contrast to the disturbances witness in the pollen record in response to hunter-gatherer activity by Hörnberg and others (2005) at these sites just discussed, Segerström (1990) suggests the relatively open conditions, displayed in the pollen record from 6000-4000 BP at Kvarnmyran in Jokkmokk Municipality, are not clearly human induced and probably reflect natural modifications to the vegetation developing along the river shores, despite archaeological remains indicating exploitation during this period. This differing interpretation highlights some of the

difficulties of discriminating between natural and subtle human impacts in the palaeoecological record in the boreal forest. Caution must be taken in trying to push evidence for subtle change in the pollen data too far, and in confidently assigning such environmental changes to human impacts based on the existence of nearby archaeological remains.

Detection of localised disturbances may be further hampered when samples are taken from the peripheral areas of activity. As pre-historic archaeological features are often not currently visible in the landscape of such areas, and therefore the past spatial use of an area remains unknown, it may not be possible to determine if the subtle signal reflects the sampling regime or is a true reflection of limited human impacts. The effects of land use around a settlement site will have created gradients of impacts spanning outward from the central activity area (Josefsson 2009). It has been suggested that an area of up to 1 km from the settlement may have been routinely exploited by Sámi for wood, food and grazing as part of a hunter-herder economy (Josefsson *et al.* 2009).

Hörnberg and others (1999) postulate human induced changes to the environment began c. 2000 years ago at the sites of Marrajegge and Marrajåkkå in the Scandes Mountains, including changing vegetational composition provoked by fire, grazing and trampling. These impacts on the vegetation, along with severe climatic conditions, were important factors in the eventual shift from the mixed forest type with abundant dwarf shrubs and mosses, to *Picea-Cladina* forest in this area. Occurrences of particular pollen types favoured by disturbance, including *Rumex* sp. and *Chenopodiaceae*, alongside increased charcoal and the presence of dated archaeological remains, led these researchers to suggest that transient hunter-gatherer Sámi groups used fire to manipulate the landscape, encouraging a vegetation mosaic more attractive to grazing animals, and that their intentions were initially targeted to improve hunting and only later to provide a valuable winter food source for domesticated reindeer.

Aronsson (1991; 1994) identified the first indications that small numbers of reindeer were being gathered together at the studied sites in northern Sweden in the 1<sup>st</sup> millennium AD. Aronsson (1991) has also studied the modern pollen rain from reindeer herding sites across northern Sweden, establishing that the detection of vegetation changes caused by reindeer herding activity is possible only within 50m of the affected area (Aronsson 1991, 47-49). From his analysis of modern data he suggests that reindeer herding within the forest can be detected in the pollen record through higher occurrences of Poaceae and instances of *Rumex* pollen, often alongside certain other herb types (Aronsson 1991, 47). An analysis of the fossil pollen from historic reindeer herding sites found assemblages of pollen similar to those seen at the modern sites to be identified, including the increased representation of grasses and the presence of pollen of Chenopodiaceae, Asteraceae, Caryophyllaceae, *Epilobium* and Apiaceae (Aronsson 1991, 49). This extensive study was preceded by testing of the pollen catchment area, and it provides a rich suite of evidence from which Aronsson (1991) was able to draw various conclusions regarding the pollen evidence at reindeer herding sites in northern Sweden over the last 2000 years.

At nearly all of the sites where reindeer herding is historically attested, the clearest vegetation changes were found within the last few hundred years (Aronsson 1991, 99). The evidence includes a diverse ‘culture-indicator’ package, with markedly increased frequencies of grass and herb pollen and the presence of ruderal plants, signifying disturbance. Signals of vegetation changes from earlier than this are generally weaker, and may consist of intermittent signs of increased grasses at certain horizons, but with only a few instances of other plants considered to benefit from disturbance. Indications of agricultural practices are extremely rare in the pollen profiles, suggesting that cultivation was not an important part of the economy at the studied sites (Aronsson 1991). Aronsson (1994) suggests that the suite of pollen indicators found at the studied sites, which are often considered as indications of agriculture and more permanent settlement, are in this case a reflection of periodic settlement. This suggestion is influenced by the understanding of the timing of

settled farming groups in the northern interior of Sweden, which is determined to have taken place since the 1800s in this region (Aronsson 1994).

From three sites in north-east Finland, Hicks (1976) found an increase in grassland vegetation in the pollen record as the landscape opened up in response to reindeer herding around 3000 years ago. Only slight evidence of human impact on the vegetation was found before this time, with infrequent finds of pollen associated with human disturbance and low NAP (non arboreal pollen) values.

Karlsson (2006) carried out soil chemical analysis at sites with associated reindeer pens as part of her research into past settlement and subsistence strategies in northern Swedish forests. She found that former activities at such sites have resulted in concentrated levels of phosphorus and organic matter in some areas, and can indicate the accumulation of waste material in areas where reindeer gathered. It is the author's opinion that the weak signal in the pollen evidence from several of the historic reindeer herding sites should be considered as perhaps relating to subtle human impacts, rather than as a firm indication of reindeer herding, as Karlsson concludes. Stronger indications of human impact occur in the pollen record from the Early Medieval Period, with more marked changes in the environment (Karlsson 2006). The environmental evidence is thought to suggest that these sites were used intermittently by small numbers of people (Karlsson 2006). However, sites used periodically, but for significant lengths of time, and those used regularly, but for shorter periods may be difficult to differentiate between in the palaeoenvironmental evidence, and this aspect of understanding past occupation in northern Sweden requires further exploration.

The pollen recovered from a mire close to the site of Einehrammet, north of Lake Inari, in Finnish Lapland, indicates a phase of local pine reduction combined with an increase in nutrient- and light-demanding vegetation, which are thought to be the result of the establishment of the settlement site (Hicks 1993). Grasses then came to dominate. Abandonment of the settlement is indicated as birch invades, followed by the recovery of the pine woodland. It is clear from this that the area, considered an

uninhabited wilderness, has been altered by human activity, and is far from untouched (Hicks 1995). Although pollen considered as indicative of human disturbance is present in other parts of the column, these occur without any co-occurring changes in tree-pollen or other indications of human activity, and therefore only one phase of occupation can clearly be identified from the pollen record.

At Nukkumajoki itself, Carpelan and Hicks (1995) described increased frequencies of *Betula* and herbaceous pollen taxa within the two cultural layers taken from a Finnish Kota (hut) wall, with taxa including Ericales, Poaceae, *Urtica*, Chenopodiaceae, *Epilobium*, *Ranunculus* and *Lycopodium* spp. The pollen taxa recorded from the cultural layers are similar to those from Aronsson's (1991) reindeer herding sites (Hicks 1993, 139), and the changes to the vegetation that are indicated, are in contrast to the minimal impacts inferred from in the pollen diagram from Karlsson's site RAÄ 300, considered to have been used in winter.

In the authors opinion, the limited impact seen in the pollen record at the sites in northern Sweden which Karlsson (2006) proposes were used in winter contrasts to the more marked impacts recorded at the winter village sites studied by Hicks (1993) and Carpelan and Hicks (1995), considered in the preceding paragraphs. The contrasts between these findings could indicate that the seasonality of occupation, and possibly the associated economic practices, are less important in shaping the environment than is the periodicity of the use of these settlement foci. This would suggest that repeatedly-used seasonal settlements will have had more significant and long-term effects on the local environment than sporadically used sites.

It is apparent from the discussed studies that seasonal occupation by indigenous Sámi groups could create notable changes in vegetation of the boreal forest, visible in the palaeoecological record (Figure 5.1). However, these impacts are not always clearly separable from natural influences, and caution must be taken in linking subtle vegetation changes to human impacts. The growing pollen literature is enabling the development of a 'culture-indicator' package of traditional Sámi settlement in the boreal forest of northern Scandinavia, allowing the impacts of indigenous activity to

be assessed and, perhaps, more easily recognised. However, our understanding of the nature and timing of such activities remains rather coarse, and it will be necessary to utilise the localised, and fine-grained evidence that can be gained through insect fossil analysis to both expand on, and refine, current understandings of Sámi settlement and subsistence in northern Sweden.

### **5.2.2 Early agriculture**

As people settled in the northern Swedish landscape and agricultural practices intensified, the footprint of human impact becomes more legible in the palaeoecological record, as evidenced in the palaeoenvironmental studies discussed below (Figure 5.1). The transition to an agricultural economy took place over several decades/centuries, the result being that there is a period of overlap in which herding-hunting and arable farming were being carried out simultaneously within the same landscape.

A study by Hicks (1988) in northern Finland sought to determine the extent to which differences in land use related to farming could be distinguished in the pollen record. The method used also involves a consideration of the historical evidence of land use, and an understanding of the expected pollen spectra as a result, based on comparative modern studies. This approach can inform the interpretation of the fossil pollen, indicating the types of activity being carried out. Although there are many complications within this process, for example with the modern activities in practice not equating in character with older ones, and the fact that some activities may be too subtle to result in clear signals in the pollen record (Hicks 1988), this interesting approach highlights the importance of archaeological/historical knowledge of the relevant area, and the use of modern studies to aid interpretation.

#### **5.2.2.1 South and Central Sweden**

The establishment of arable farming at Skallskog, in central Sweden, from around the 12<sup>th</sup> century, saw the use of fire to clear the forest (Segerström and Emanuelsson 2002). This was indicated by the presence of increased microscopic and macroscopic charcoal identified in samples taken from mires adjacent to the farm shieling,

alongside a significant decline in *Betula* pollen. The creation of hay fields followed, as is visible in the high occurrence of Poaceae and *Cyperaceae* pollen, and crop cultivation of *Hordeum* and *Secale cereale* took place in the environs. Fire was later used to enhance grazing in the forest, and grazing and trampling further influenced the vegetation, encouraging an open landscape and inhibiting the regeneration of trees. The impacts of agrarian land use were severe and long-lasting around this site (Segerström and Emanuelsson 2002), and a consideration of other farming sites in central and southern Sweden (e.g. Segerström *et al.* 1996; Emanuelsson and Segerström 2002; Gustavsson *et al.* 2009a) show similarly marked and enduring changes to the environment as a result of settled agriculture.

In central Sweden, the decline in tree pollen and subsequent increase in cereal, grass and herb pollen discussed by Emanuelsson and Segerström (2002) in the pollen record from Persbo, clearly indicate a mosaic landscape of patchy forest and agricultural land beginning in the 14<sup>th</sup> century. The sequence of vegetation change and the presence of charcoal during the medieval period are represented in a cyclical fashion, indicating slash-and-burn type practices extending over c.400 years (Emanuelsson and Segerström 2002).

Changes in the forest structure and composition, and increases in the representation of plants of disturbed open ground are found at Trygåsén, in Jämtland from 1000 AD (Segerström *et al.* 1996). Fire management to improve pasture is evident here from both charcoal and pollen evidence. Cattle were grazed and *Hordeum* grown, with an expansion in cultivation occurring from the 16<sup>th</sup> century. Increases in *Cyperaceae* could indicate manipulation of the mire for fodder production (Segerström *et al.* 1996).

In southern Sweden at Svartmosse, insect species richness is linked with disturbance through grazing and cultivation, which created a mosaic landscape from c. 900 AD (Gustavsson *et al.* 2009a), and similarly at Stavsåkra, increased human activity results in notably more diverse insect and pollen assemblages (Gaillard *et al.* 2009; Olsson and Lemdahl 2009). Dung- and fire-dependent beetles, as well as species of

dry and exposed ground, are found alongside woodland beetles, indicating a forested environment, representing a heterogeneous landscape structure (Gustavsson *et al.* 2009a; Olsson and Lemdahl 2009). The decline in both palynological and insect species richness from the 19<sup>th</sup> century may indicate changes in the environment related to the abandonment of the traditional agrarian system and the development of a more homogenous landscape structure (Gaillard *et al.* 2009b; Olsson and Lemdahl 2009).

These studies from south and central Sweden indicate that where agriculture was practiced to a significant extent, the impacts on the landscape are detectable in a variety of palaeoecological proxies and various forms of land use can be identified, such as the use of fire, crop cultivation, hay-making and stock keeping. The signal for such activities in the palaeoecological is clear, with significant increases in pollen indicative of grasses, herbs and cereals, and often the occurrence of high instances of charcoal concurrent with declines in tree-pollen. In the case of the insect fauna, fire and grazing disturbance is clearly reflected in pyrophilic and dung species (Gustavsson *et al.* 2009a; Olsson and Lemdahl 2009). This enables such activities to be more easily detected in the palaeoecological record than the subtle indications of indigenous periodic exploitation, as previously discussed.

#### **5.2.2.2 Northern Sweden**

In both lower Umeälven and in coastal Medelpad, the earliest explicit evidence of cultivation occurs during the Late Bronze Age (Engelmark 1976, 1978). In Umeå, agricultural activity ceased during much of the Iron Age and a lull in agricultural activity took hold, perhaps associated with a worsening climate, until a revival in the Mid-1<sup>st</sup> millennium AD, when a decline in spruce and the presence of cereal pollen are noted (Engelmark 1976, 99). Similarly in Medelpad, agricultural activity was low during much of the Early Iron Age in both coastal and inland sites, suggesting that permanent agricultural endeavours may have been absent (Engelmark 1978).

Indications of the development of permanent agriculture during the Late Iron Age along the Västerbotten coast were also found by Segerström (1990). Pollen analyses



of material from the vicinity of archaeological sites in the Tornio Valley, in the far northeast of Sweden, have shown clear indications of forest clearance and agricultural practices occurring long before written evidence for this activity, suggesting a permanently occupied agricultural landscape existed here from the 12<sup>th</sup> century (Sundström *et al.* 1981). At one site cereal pollen has been found as early as 2500 BC (Sundström *et al.* 1981, 268).

The interior north shows a different picture from the coastal regions where the study of agricultural expansion has focused. From inland Medelpad subtle indications for the use of pasture occur from around 2000 years ago. From 200 AD cereal pollen is found, and this marks the beginnings of an increase in grass and cereal pollen alongside a marked spruce decline, indicating the beginnings of settled farming (Engelmark 1978, 46-47).

Josefsson and others (2009) studied the palaeoenvironmental evidence from three sites in the Tjeggelvas Nature Reserve. One site had no visible evidence of past human settlement (low impact area), one site was a Sámi settlement site (Munka), and the third site was a 19<sup>th</sup> century settlement where hay-making was carried out and domesticated animals kept (Akkapakte). The pollen record clearly demonstrates vegetation changes over the last thousand years, which are ascribable to local human impacts rather than climate change (Josefsson *et al.* 2009). At Munka, changes in tree composition, increases in apophytes (particularly grasses), the rise in herbs such as *Ranunculus* spp., and *Rumex acetosa/acetosella*, and the presence of *Cerealia* pollen all occur over the last four centuries. This reflects settlement in the area by the Mountain Sámi along with possibly evidence of cultivation being carried out. Similarly at Akkapakte, an increase of birch at the expense of pine, and the inclusion of apophytes, particularly sedges, and herbs associated with disturbance are observed in the pollen record since 350 BP. Josefsson and others (2009) suggest the absence of any indication of cultivation in the pollen record may be a product of the distance of the sample from the settlement and possible area of past cultivation. The results from Akkapakte are considered to reflect traditional Sámi subsistence strategies and later agrarian land use, the latter carried out as part of a settled regime over the last 150

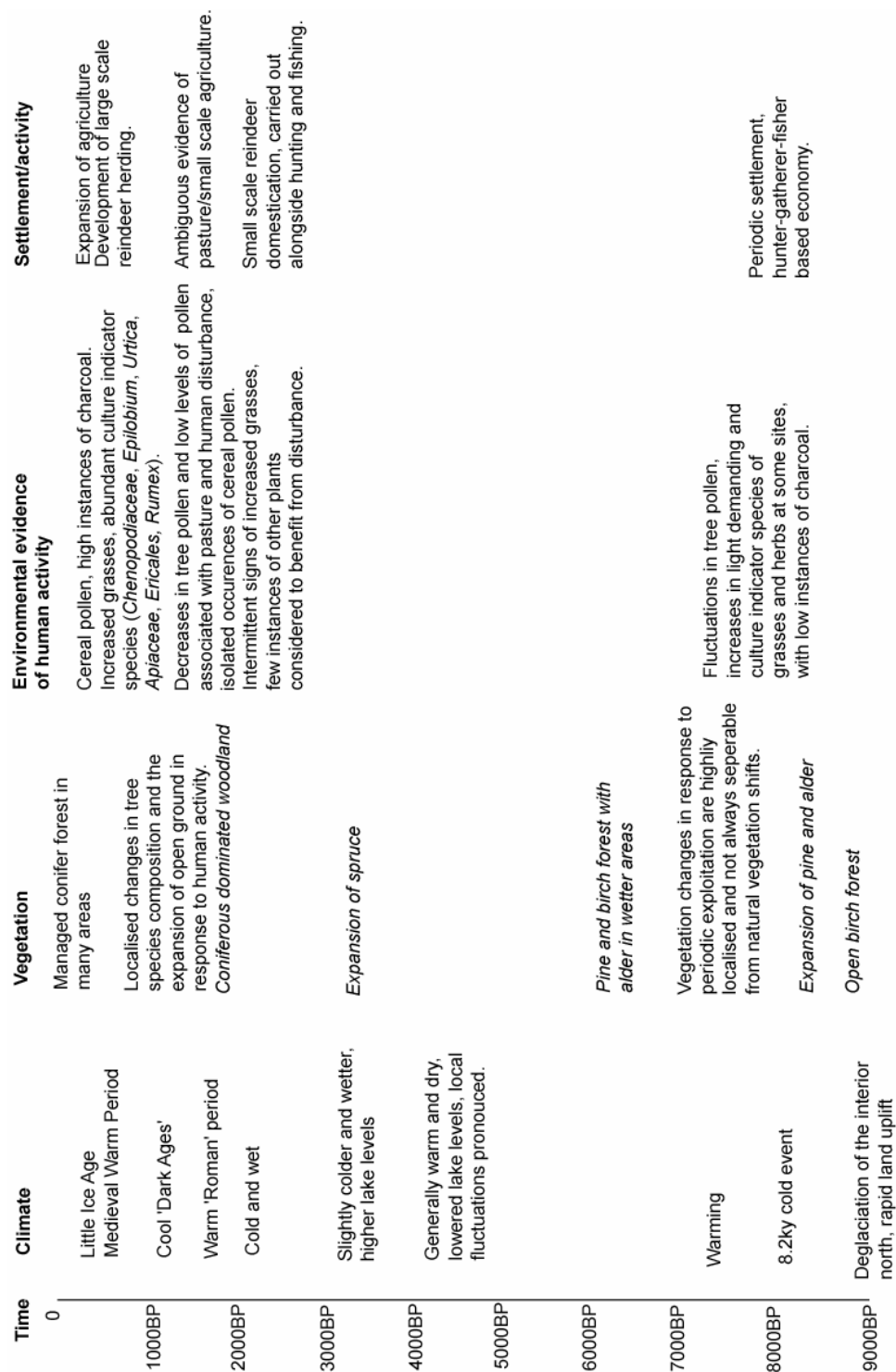
years. This study is a valuable one, with analysis of three sites within the same locality enabling an assessment of the impacts of different types of land use, with the site with no human impact able to act as a natural base-line. Furthermore, local influences from human activity can be more easily separated from climatic influences, as it can be postulated that the effects of the latter would be visible across all three sites simultaneously. The pollen evidence from this study is supported by charred particle and loss-on-ignition analyses (Josefsson *et al.* 2009), further upholding the conclusions of this work.

In Edefors, 100km inland from Luleå, pollen evidence indicates subtle openings in the landscape from c. 500 AD (Segerström 1990). Although Segerström interprets these subtle openings as indicating the beginnings of agriculture, discriminating between small scale, non-cultivating activity and reindeer herding in the palaeoecological record is difficult at sites in the boreal forest zone, with both activities encouraging the clearance of the forest and accompanying disturbance of the ground layer. The evidence could potentially relate to the increasing impacts of reindeer herding in the locality, rather than early agriculture, as Segerström suggests. At Edefors, sporadic finds of cereal pollen are first found from the 8<sup>th</sup> century AD and the isolated occurrences of cereal pollen only become accompanied by indications of a more extensively cleared and more disturbed landscape from the 13<sup>th</sup> century AD. Overall the indication of settled agriculture of any significant extent in this locality is highly ambiguous until the Post-Medieval Period (Segerström 1990).

Palaeoecological studies of agriculture in the interior of the studied areas of Västerbotten and Norrbotten are rare. At Lappmyran, van der Linden and others (2008) found evidence of human impact from around 1500 AD, where pollen of *Juniperus*, Poaceae and *Rumex acetosa*-type suggest open, disturbed meadow. Coprophilous fungi including *Chaetomium* and *Sporormiella*, may indicate grazing animals. Some 50km inland from the Västerbotten coast, indications of more open conditions that may be a result of small scale agriculture dating from 1500 BP were identified around Vindeln, although they could similarly be connected with reindeer herding (Barnekow *et al.* 2008).

In comparison to the highly discernible changes in the environment at farming sites from the limited studies so far carried out in the south and central parts of Sweden, the impacts of early farming so far found in the Västerbotten interior are comparatively subtle. These studies indicate that impacts of the earliest potential agricultural endeavours were slight, and do not appear to have included extensive cultivation, but perhaps focused on small scale stock-keeping (Figure 5.1). Furthermore, deciphering such stock-keeping practices from reindeer herding may not be possible in the pollen record. Ascribing such activities to specific ethnic groups is difficult where historic records of land use do not provide guidance, and there may be a tendency to ascribe indications of cultivation to settled European groups due to an understanding that they were the main proponents of agriculture in the studied area. However, it is apparent that this could lead to erroneously assigning environmental activities to particular groups, and a degree of caution must be taken in being over-eager to tie environmental changes to the particular economic practices of different ethnic groups.

Chapters 4 and 5 have attempted to provide an overview and analysis of the current evidence relating to natural climatic and vegetation changes occurring in the Mid-Late Holocene landscape, and to both Sámi hunter-herder groups and the later agricultural enterprises of incoming settlers. The main events have been summarised in Figure 5.1 in order to collate this evidence, bringing it together in a way that highlights the various influences at play upon the Holocene landscape over time.



**Figure 5.1** Summary of climate and vegetation changes and evidence of human activity in the inland north of Sweden during the Holocene. The events in *italics* under the 'Vegetation' section are natural vegetation shifts which generally characterise the area. Evidence compiled from Sonesson (1974); Karlén (1976); Bradshaw and Zachrisson (1990); Segerström (1990); Aronsson (1991); Hyvärinen and Alhonen (1994); Almquist-Jacobson (1995); Carpelan and Hicks (1995); Engelmark (1996); Hörnberg and others (1999); Barnekow (2000); Korhola and others (2000); Seppä and Hammarlund (2000); Rosén and others (2001); Grudd and others (2002); Snowball and others (2002); Hörnberg and others (2005); Karlsson (2006); Barnekow and others (2008); Grudd (2008); Bjune and others (2009).

## **6 Previous Palaeoentomological Work in Scandinavia**

### **6.1 The development of palaeoentomology in Scandinavia – an introduction**

The insect fossil record is the primary source of data being explored in this research. This chapter discusses the development of the discipline, and considers some of the most significant insect fossil research so far carried out in Scandinavia, highlighting the potential of this method in reconstructing past vegetation development, climate change and human activity.

Henriksen's initial work on Lateglacial and Postglacial faunas in Scandinavia (Henriksen 1914), was followed by his 1933 study of the Quaternary insect fauna from sites investigated in Sweden and Denmark. At several of the sites studied in southern Sweden (Henriksen 1933)(Figure 6.1), only a single specimen has been identified, including at the sites of Järavallen, Eslöve Mosse, Trelleborg, Lindved and Skurup. At the site of Femsølyng in Denmark, one of the most diverse deposits considered by Henriksen (1914; 1933), the assemblage consists of open heath species such as *Cicindela campestris* L. alongside beetles more commonly found in deciduous woodland environments, including *Carabus hortensis* L. and *Abax parallelepipedus* (Pill. and Mitt.), providing information on the environment of the area in the Lateglacial and Holocene period. These early studies lacked stratigraphic refinement and the use of radiocarbon dating, but were nevertheless pioneering in the development of palaeoentomological research in Scandinavia, and in considering the early colonisation of Scandinavia during the Lateglacial.

Lindroth's early work involved the analysis of previous palaeoentomological studies carried out in Sweden (Lindroth 1948). Deposits such as those analysed at Långsele, Pilgrimstad and Härnösand (Figure 6.1), display a range of beetles indicative of wet heaths, with limited tree-dependent species and rare inclusions of dung beetles of *Aphodius*, revealing new insights into the landscape of the Early Weichselian interstadial, and his incisive work contributed to a better understanding of taphonomy and morphological characteristics aiding identification (Lindroth 1948).

His work alongside Coope at Leveäniemi further contributed to the emerging picture of the last interglacial in Sweden, finding that many species from this site in Lapland are currently found only in more southerly areas, suggesting that temperatures were similar to, or warmer than today (Lindroth and Coope 1971).

Lemdahl's contribution has been at the forefront of palaeoentomological research in Scandinavia since the 1980s (Berglund *et al.* 1984), with the study of insect remains from many Lateglacial and Holocene sites. This included an early study highlighting the use of insect fossil remains in investigating past climate in Scandinavia, with the reconstructed trends in summer temperature regimes in synchrony with the palaeoclimate model devised from the British fauna by Coope (1975, 1977) during the Weichselian Lateglacial (Berglund *et al.* 1984). Ten years later Atkinson and others (1987) developed a palaeoclimate curve using the Mutual Climatic Range Method (MCRM) which agreed well with this earlier model. This method continued to develop, with its accuracy repeatedly tested, building confidence in its robustness (discussed further in Section 7.7).

## **6.2 Southern Sweden**

The main focus of insect fossil investigations in southern Sweden has until recently centred on Lateglacial and Early Holocene deposits, considering vegetation development and climate change. A study by Lemdahl (1997b) collated the growing faunal lists from south Swedish Late Weichselian and Early Holocene sites (Figure 6.1), enabling patterns in faunal changes to be synthesised, with the conclusion that refugia on the continent hosted a fauna that was later able to migrate into southern Sweden, with few species surviving in ice-free refugia in Fennoscandia. After deglaciation the most mobile arctic/subarctic species moved rapidly into the sparse landscape, including species exploiting the aquatic environment such as *Haliphus confinis* Steph., followed by beetles exploiting the sparse vegetation of herbs and shrubs, such as *Miscodera arctica* (Payk.) and *Amara alpina* (Payk.), founding a population of arctic/subarctic species by around 12,200 BP (Lemdahl 1997b). Species such as *Cymindis macularis* Fisch. which requires warmer temperatures are found during the following climatic amelioration phase, before the Younger Dryas drives

the re-emergence of the arctic fauna once again. During the Early Holocene the landscape becomes increasingly heterogeneous and temperate species such as *Calosoma inquisitor* (L.) come to replace the arctic fauna (Lemdahl 1997b).

Investigation of Holocene deposits in Southern Sweden includes pollen, mollusc and insect evidence from Holocene deposits at Hanö Bay on the southern coast of Sweden, which reflects the dynamics of the environment through the stages of the *Ancylus* transgression and the later *Littorina* transgressions (Gaillard and Lemdahl 1994). The Colepoteran evidence suggests that small water bodies with rich vegetation typified the local environment, with high numbers of aquatic beetles found in stagnant water such as *Ilybius fenestratus* (F.) recovered from the assemblage. Dung beetles *Geotrupes vernalis* (L.) and *Aphodius* sp. indicate open, sunny localities and the presence of dung. The application of the MCR method to the insect assemblages, although giving low resolution results due to the small numbers of MCR species used for reconstruction, may indicate summer temperatures similar to today's or warmer during the time around 9500-8000 BP.

Insect fossil analysis carried out by Lemdahl (1988) from a lagoon close to a prehistoric settlement as part of the multidisciplinary Skateholm project, found a range of species never before found from postglacial south Sweden, including the bug *Valgus hemipterus* L. a species commonly with a much more southerly distribution. The environment is reconstructed from the fauna, indicating the development of the lagoon from an alder swamp during the Late Atlantic and the presence of brackish sea-shore species such as *Ochthebius auriculatus* Rey, perhaps connected to rising sea levels, during the Early Subboreal.

Recent palaeoentomological investigations have turned towards developing a fuller understanding of environmental change and human impacts throughout the Holocene period, with studies of Late Holocene deposits becoming increasingly frequent.

In southern Sweden, the palaeoecological evidence from rare Holocene successions covering a period over almost 11,000 years has been studied at two sites - Storasjö

and Stavsåkra (Figure 6.1) - using a number of techniques including insect fossil analysis (Gaillard *et al.* 2009; Olsson *et al.* 2009; Olsson and Lemdahl 2009a; Olsson and Lemdahl 2009b). The long-term approach is significant, and enables the impacts on the environment through time to be thoroughly studied against the natural baseline. The Early Holocene assemblages host an increasing tree- and leaf-litter associated fauna as the coniferous woodland develops (Olsson and Lemdahl 2009a; Olsson and Lemdahl 2009b). At Stavsåkra, species associated with, but not restricted to dung are found in the Early Holocene, such as *Platystethus arenarius* (Geoff.). Olsson and Lemdahl (2009a) suggest this as indicative of extensive grazing. However these species may also exploit a range of decomposing vegetative matter.

In contrast, the absence of dung beetles at Storasjö and Stavsåkra during the Mid-Holocene period suggests that grazing disturbance was low (Olsson and Lemdahl 2009a; 2009b). It is only in the Late Holocene (from c. 2400 BC) that dung beetles of *Aphodius* spp. are found in number alongside increases in species feeding on plants of disturbed ground and in open localities, including *Trechus quadristriatus* (Schrank), indicating human disturbance (Olsson and Lemdahl 2009a). The pyrophilic beetle *Agonum bogemanni* (Gyll.) is found in the assemblages until the 19<sup>th</sup> century, when both fire suppression and the reduction of the dead wood habitat is thought to have led to its decline (Olsson 2009, 35). This research highlights the use of insect fossil studies in considering past woodland structures, as well as natural and human induced disturbances.

In Svartmosse, southern Sweden, a mosaic landscape structure typified by deciduous woodland with dead wood, grazing and some areas of cultivation are interpreted from the Late Bronze Age, with a diverse insect assemblage (Gustavsson *et al.* 2009a). Increasing exploitation of the landscape by human groups is witnessed from around 900 AD with dung beetles and species found in open areas, such as *Calathus* spp. and *Apion* spp., becoming prevalent. Dead wood species such as *Denticollis rubens* Pitt. and Mitt. and *Melanotus castanipes* (Payk.) are also present (Gustavsson *et al.* 2009a). Marked changes in the environment are demonstrated in the insect and pollen record with a change in tree species composition and the appearance of beetles



which are confined to beech, such as *Rhyncaenus fagi* (L.). This is considered to have been driven by human activity from the 14<sup>th</sup> century AD, demonstrating the anthropogenic, rather than natural origin of the beech forests found in the region today.

Hellqvist's (1999a) work introduced one of the first significant studies of insect fossil remains from archaeological deposits in southern Sweden (Figure 6.1). His thesis provided new insights into the local environment and activities around the early towns of Uppsala and Novgorod, and the land use around Iron Age farms. The extensive insect fauna studied from a series of wells included a diverse range of dung beetles, alongside open ground and woodland species, in a mosaic landscape of agricultural land and old forest shaped by Iron Age farmers (Hellqvist 1999b). Synanthropic elements include *Ptinus fur* (L.) from the nearby buildings. Other synanthropic species, such as the hydrophilid *Cercyon unipunctatus* (L.), were found frequently in the 12<sup>th</sup>-15<sup>th</sup> century settlement deposits from the block Bryggaren, Uppsala (Hellqvist and Lemdahl 1996). Species that are rare today in the south of Sweden indicate changes to the environment since the medieval period. These include *Xyleborus monographus* (F), a scolytid found on old deciduous trees, indicating the loss of this habitat over time, and the dung beetle *Aphodius subterraneus* (L.) which has been negatively affected by the change in agricultural resource use which has limited the extent of its preferred grazed meadow habitat. Slightly warmer conditions than that of present may have prevailed, with species such as *Amara fusca* Dej. having more southerly distributions today (Hellqvist and Lemdahl 1996). The indication of open, cultivated land is prevalent in the assemblage, with a later change to a dominant economic practice of stock rearing around the 15<sup>th</sup> century. Medieval insect assemblages (c. 15<sup>th</sup> century) from a well in Halland, southern Sweden were also considered by Gustavsson (2009), where the fauna allow a reconstruction of land use in the local area, and the disappearance of dung beetles in the uppermost part of the sequence is considered to relate to site abandonment.

### 6.3 Northern Sweden

Unlike in southern Sweden where the considerable number of Lateglacial and Holocene studies have enabled comparison of faunal assemblages and synthesis of landscape and climatic reconstructions across the area, the rarity of palaeontomological work carried out in northern Sweden means that there are no such long-term views, and only one extensive inter-site comparison (Lemdahl 1997a) have yet been completed.

Robertsson and García Ambrosiani (1988) analysed fossil remains relating to the Late Pleistocene at the site of Boliden, where only cold tolerant, heath related species *Eucnecosum brachypterum* (Grav.) and *Acidota quadrata* (Zett.) were identified. Lemdahl investigated Early Weichselian beetle assemblages in Norrbotten, where cold dwelling species indicate summer temperatures several degrees cooler than today's, including *Elaphrus lapponicus* Gyll. and *Holoboreaphilus nordenskioeldi* (Mäklin)(Aronsson *et al.* 1993). *Boreaphilus henningianus*, *H. nordenskioeldi* and *Olophrum boreale* were recovered from an assemblage indicative of a tundra environment.

The high proportion of fauna associated with aquatic and riparian conditions at Leveäniemi, Lapland (Lindroth and Coope 1971), has been considered alongside more recent multiproxy evidence to suggest high water levels during the early Eemian (Kolstrup 2007). Fluvial transport of flora, and perhaps also beetle fauna, from continental Europe may account for the quick rate of immigration suggested by the similarities in the vegetation (Kolstrup 2007).

In the northeast of Norrbotten, Lemdahl (1997a) has applied MCR to the recovered Coleopteran remains from 17 sites with Early Weichselian interstadial deposits, finding temperatures lower than that of today. In total, nine species are not currently found in Fennoscandia, including *Agonum exaratum* (Mann.) with many others restricted to more northerly areas. This study demonstrates the possibility of detecting severe climatic change in the northern Swedish fossil fauna. Whether the more subtle Late Holocene climatic changes will be detectable through the insect

fossil record, and whether these changes can be observed through the ‘noise’ of human activity, has yet to be determined. With insect distribution patterns being determined by factors other than climate, e.g. with introduction of species to an area through trade, then the presence of species may be more indicative of human activity rather than climate (Kenward 1975, 1978, 1985). Furthermore, separating natural, climatic vegetation changes from human impacts becomes increasingly difficult, especially where the changes are subtle.

At many of the sites studied by Lemdahl (1997a), the beetle assemblage was low in diversity, with species characteristic of very open environments. Lemdahl notes the similarity of the recovered fauna with that of other Early Weichselian deposits in Scandinavia and suggests tundra may have typified much of the Scandinavian landscape during the interstadials.

Currently the only insect fossil evidence from an Early-Mid-Holocene site in Västerbotten is by Buckland (2007) at Hemavan, close to the Norwegian border. From the Early-Mid-Holocene the fauna reflect the development of the bog, surrounded by fluctuating levels of woodland, with tree-dependent species generally quite low and indicative of mainly deciduous woodland and *Salix* stands. Indications of old and rotting wood are absent. The pollen evidence, studied by Engelmark (1996), indicates that woodland was more prevalent than suggested in the insect fauna, perhaps a reflection of the regional rather than immediate local environment. Possible cooler conditions are indicated from the insects in the Early Holocene with the presence of *Acidota quadrata* (Zett.) in the oldest sample, a species whose thermal tolerance is lower than summer temperature averages of the area today, in the oldest sample. However interpretation of the assemblages is hindered by the low numbers of species recovered in several samples.

## **6.4 Norway**

In Norway, early work includes the investigation of insect fauna from Brumunddal, south-east Norway (Figure 6.1), investigated by Coope (Helle *et al.* 1981). The presence of species found in tundra landscapes, including *Diacheila polita* (Fald.)

and *Amara alpina* (Payk.), indicate low temperatures occurring around the Early Weichselian Interstadial, contrasting to the earlier warmer, forested landscape (Helle *et al.* 1981).

Lemdahl identified the insect faunal remains of late Allerød age from a peat deposit at Godøy in western Norway (Birks *et al.* 1993). The insect assemblage across the analysed samples does not vary much in composition, predominantly with species which dwell in heath and meadow habitats such as *Notiophilus aquaticus* (L.) and *Amara quenseli* (Schön.), and diversity is low. Several of the species found, including *Olophrum boreale* (Payk.) and *Boreaphilus henningianus* Sahl. have thermal tolerances that indicate temperatures that were perhaps cooler than the present day, and alongside the temperature reconstructions from the plant remains, indicate severe cooling of the Younger Dryas.

Indications of rapid environmental change at the onset of the Younger Dryas stadial, as witnessed in the southern Swedish insect fossil record, was also found at Kråkenes, western Norway, where few beetles appear to have been able to withstand the severe conditions of the period (Lemdahl 2000). Faunal diversity increases at the commencement of the Holocene period, with the colonisation of dwarf-shrub and heath vegetation, and aquatic fauna re-establish.

The study of insect fossil remains at archaeological sites in Norway has proved integral in building an understanding of aspects of past living conditions, on-site activities, economic underpinnings and trade. Investigation of the insect remains from the Viking Age site of Kaupang, south-east Norway, produced evidence relating to trade, patterns of occupation, and economic practices at the site (Buckland *et al.* 2001; Barrett *et al.* 2007). From waterlogged deposits investigated in 2002, the insect species recovered were primarily those reflecting indoor accumulations of plant material and animal matter, suggesting redeposited house floor material (Barrett *et al.* 2007). The beetle *Omosita colon* (L.) has been found at the site in abundance (Buckland *et al.* 2001; Barrett *et al.* 2007), and alongside other species that may exploit animal skins and bones, which could indicate the storage of animals

skins (Barrett *et al.* 2007, 299). It is unclear whether the limited number of synanthropes could be indicative of periodic site use, with no build-up of appropriate warm habitats and no durational stability, or is a result of the short duration of site use overall (Barrett *et al.* 2007, 303).

In coastal Norway, Buckland and others (2006) studied the insect fauna from Langenes, known as a medieval fishing station, providing evidence pertaining to the activities being carried out at this site. Species such as *Sitophilus granarius* (L.) and *Oryzaephilus surinamensis* (L.), which infest stored grains, were likely imported into the site in grain supplies. These supplies may have supplemented the diet of the fisherman themselves, or have been utilised as part of a more far-reaching trading system. Several species were recovered at the study site that were outside their current northern distribution limit, including *Metopsia retusa* grp. and *Helophorus grandis* Ill., however it is likely that these species were also inadvertently introduced on boats travelling from the south, rather than indicators of climate.

## **6.5 Denmark**

Early work in Denmark was mainly carried out by Henriksen (1933), who studied insect faunal remains from both southern Sweden and Denmark (Figure 6.1), and few major investigations of Coleopteran remains have since been carried out. Böcher described a restricted fauna from Kobbeltgård on the coast of Møn, where, alongside other proxy evidence, the arctic environment of the Mid-Weichselian could be reconstructed (Bennike *et al.* 1994). More recent investigations include that at Nørre Lyngby, Jutland, where radiocarbon dating of the stratigraphy has provided a means to consider the environment of the area during the Allerød period through the study of the insect faunal remains (Coope and Böcher 2000). Colder temperatures are inferred from the assemblage of beetles, consisting of many that currently have a much more northerly distribution, fitting with the pattern seen during this period from elsewhere in Scandinavia.

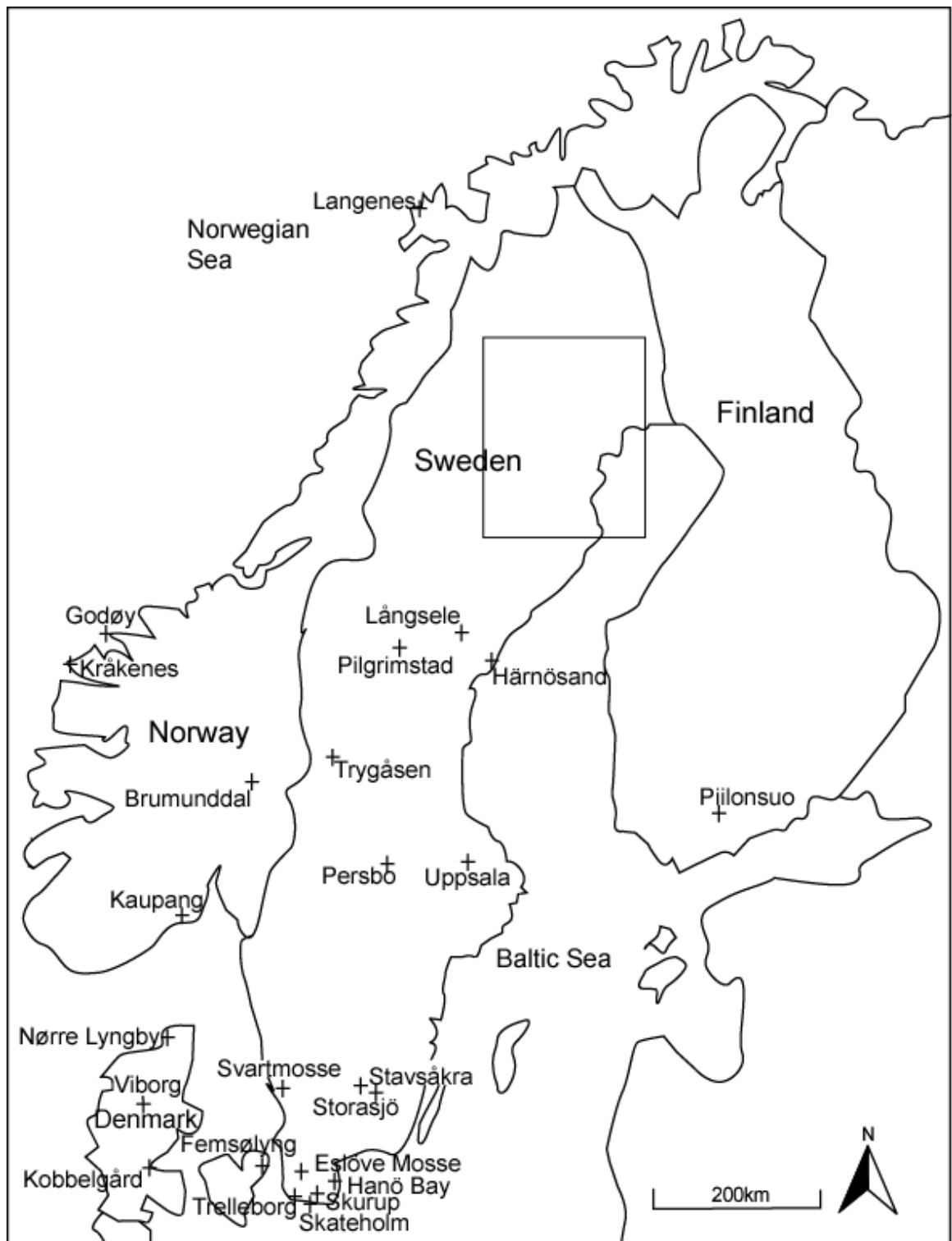
Insect remains from archaeological sites have also been investigated and can be considered alongside material from medieval deposits elsewhere in Scandinavia. The

low number of synanthropic species from the medieval town of Viborg, Denmark, led Kenward (2002) to consider the reasons for such paucity, perhaps related to the short duration of the site, or the types of activity taking place. However, human fleas and lice were found, albeit in low numbers, and some fauna indicative of decomposing material parallels that found from other medieval deposits in Scandinavia and Britain, including *Platystethus arenarius* (Geoff.), *Oxytelus sculptus* Grav. and *Cercyon atricapillus* (Marsham).

## **6.6 Finland**

The investigation of natural Holocene deposits by Koponen and Nuorteva (1973) at the site of Piilonsuo, Finland found a highly diverse assemblage of insect fauna, allowing new understandings of the development of the Holocene woodland over time, and the disturbance factors within it. An increase in woodland species, particularly of coniferous dwelling scolytids such as *Pityogenes quadridens* (Hartig), is witnessed over time. Indications of dead and rotting wood, open exposed areas and of grazing, with *Aphodius* dung beetles, are all present.

MCR analysis of insect faunas studied by Bondestam and others (1994) at sites in Karelia, Finland again found rapid changes in climate from the Younger Dryas to Holocene period, and the appearance of temperate beetles replacing the arctic/subarctic tundra fauna.



**Figure 6.1** Map showing the central and southern Scandinavia sites mentioned in the text. The study area is indicated.

## **7 Methodology**

### **7.1 Site selection**

The aim to assess human impacts on the northern Swedish landscape over time necessitated the analysis of fauna from an area where evidence of human activity is locally absent, and from a period when human influence on the landscape is thought to have been minimal. Sampling from a natural base-line site also facilitates a more straightforward consideration of climate change and natural disturbance factors, which this research hoped to investigate.

The study of insect fossil remains, both from sites used on a periodic basis by Sámi groups, and from those used on a more permanent basis by incoming settlers, in order to assess the environmental impacts and visibility of each in the palaeocological record, required access to areas adjacent to studied archaeological features and/or with associated historical evidence. However, archaeological sites in the north have been affected by the dynamic processes of landscape change. Natural processes, such as alteration of shorelines and lake drainage systems, the formation of peat bogs and the over-growth of vegetation are factors which have affected the survival and visibility of older sites on the landscape (Aronsson 1991; Bergman *et al.* 2003, 2004; Hörnberg *et al.* 2005). Evidence such as hearths and dwelling pits which help to identify Sámi sites, are now difficult to locate as forest grows over evidence of past occupation. More recent events connected with increased industrialisation have also had destructive impacts on archaeological sites, and on the peat bogs that preserve such a rich palaeoecological archive in northern Sweden (Östlund *et al.* 1997; Westerholm 2005), obliterating signs of past use. Furthermore, sampling within archaeological contexts depends on gaining access during times when excavations were being carried out, which was not possible during the data collection phase of this research.

Potential study sites were identified which met the criteria of the project, including some sites which had been previously investigated through archaeological excavation or palaeoecological evidence, indicating a period of use and/or nature of activity that was within the scope of the project. In particular, sites near historic marketplaces,



where interactions between Sámi and European settlers took place, were targeted. These sites were visited on a number of field trips to northern Sweden. The quality of preservation was determined, and in some instances adequate conditions were not found, which further constrained sampling from certain sites.

The insect fossil evidence from a total of six sites have been investigated in this research, and can be summarised as follows:

1. The recently cut-over peatland at Norrheden, where no archaeological features are known in the local area and sampling of sediments thought to be Early-Mid-Holocene in date was possible.
2. The reindeer herding site of Akkajärvi, an area long exploited by the Forest Sámi, and with associated archaeological remains.
3. The prehistoric settlement of Sorsele, where previous archaeological investigations have found several dwellings and associated artefacts.
4. The historic farming settlement of Gammelhemmet, established around the 18<sup>th</sup> century.
5. The historic church town and market place site of Lycksele, with archaeological evidence of earlier use by Sámi groups.
6. The historic church and market place site of Arvidsjaur, where previous archaeological and palaeoecological evidence has taken place, indicating a long history of use.

## **7.2 Sampling**

Samples were taken from peat sections which were cleaned before sampling to avoid problems of contamination, drying out and fungal attack (Coope 1986), and the sections were recorded and drawn in the field. Attention was given to variations in soil colour and consistency.

After the removal of the surface layer, samples were taken at an average of every 5cm, or following the stratigraphy. Sampling at smaller intervals is generally hindered by the difficulties in maintaining large enough sample sizes and ensuring

that the stratigraphic layers are not compromised (Coope 1986). At all sites successions were taken to the maximum possible depth to provide ample opportunity to study the environment over time.

A series of samples of approximately 3-5 litres each were collected from each site. The size of the sample depended on the particular deposit, with around 5kg the standard size in sampling for insect fossil remains (Buckland 1976; Kenward 1978; Robinson 2001). Deviations from this standard practice occurred where specific site conditions made this unfeasible, and will be discussed with reference to each particular site.

The exact location of sampling was determined by a number of factors including preservation potential (often assessed by test cores), accessibility (e.g. exposed areas away from tree roots), proximity to archaeological features and distance from modern structures/roads etc., which may have caused disturbance. At the site of Gammelhemmet, pollen cores were taken from the same locality, and in Akkajärvi insect and pollen samples were collected together, with effort to correlate the columns.

It is important to recognise that sampling biases are present, with sampling dictated by the availability of a suitable preservational environment. Certain questions have not been adequately addressed in the literature. These include (1) How representative of the regional environment is a single faunal succession? (2) How much local variation might be found in faunal assemblages taken from different sampling localities in a given region?

### **7.3 Taphonomy and preservation**

The final insect fossil assemblages recovered from a site are the end result of a long line of processes, each one of which filters and alters the original living community from which it derives (Behrensmeyer *et al.* 2000; Smith 2000). Incorporation into the sediment is first of all biased towards certain species, such as ground-dwelling insects (Smith 2000) and migratory behaviour may also affect incorporation of species into deposits (Kenward 2006). Some species may be incorporated into the

deposit from a distance, for example by wind, run-off, or bird faeces, or introduced by humans from long distances (e.g. bringing peat indoors) (Kenward 1975, 1978, 1985). It is necessary to distinguish between beetles that reflect the local population, and those that may have been incorporated randomly, or post-depositionally. An understanding of the studied environment, whether archaeological or natural, is a necessary first stage, assessing whether some elements of the insect fossil assemblage have been introduced by human activity. Careful consideration of the stratigraphy can be one useful means to determine aspects affecting post-depositional introductions such as erosion, redeposition and other forms of disturbance within the deposit. The number of individuals and species may be affected by differences in sediment type and depositional environment, and fluctuations in diversity may be useful indications of changes in accumulation rates, with higher numbers being deposited in sediments with slower accumulation rates (Buckland 2007, 172).

The present condition of faunal remains can help to elucidate the taphonomic factors involved in the formation of the studied assemblage, including the origins of the specimens, degree of disturbance since deposition and episodic drying out of the deposit (Kenward and Large 1998). Characteristic elements identified as important to record include degree of articulation of remains, presence/absence of hairs and scales, colour, evidence of thinning, crushing and rolling, and surface abrasion (Kenward and Large 1998).

Insect chitin is surprisingly tough, allowing preservation of remains in a variety of depositional environments, however preservation may be biased towards those species which are more heavily sclerotised (Robinson 2001). In their study of the morphological characteristics that influence preservation potential, resulting in taphonomic bias in the palaeoentomological record, Smith and others (2006) found that larger, more robust modern specimens were less prone to disarticulation than smaller, more fragile insects.

The preservation of remains recovered in this PhD research was good in most samples, particularly so in peat bog samples, with retention of colour, setae and

scales, and partially articulated bodies. In a small handful of samples preservation was not as good, including the basal samples at Norrheden, Sorsele and Lycksele where high levels of coarse sand and/or gravel comprised the sediment matrix, suggesting that the depositional environment was not conducive to good preservation of insect remains.

## **7.4 Sample processing**

### **7.4.1 Insects**

Sample processing followed the method devised by Coope and Osborne (1968). Extraction of insect fossil remains was achieved by carefully disaggregating the sample in warm water over a 300µm sieve to remove silt and free the beetle remains from the sediment. Paraffin was gently mixed with the residue and cold water added. This mixture was left to stand, to allow the organic remains to float as the paraffin rises to the top. Once all movement has ceased the float was retained on a 300µm sieve and washed with detergent to eliminate traces of paraffin. This process of flotation was repeated at least three times. The remnants were stored in ethanol before being sorted under a high powered binocular microscope, removing insect remains for later identification. With the less well humified samples, where a large amount of plant debris also rose to the surface, these were divided into two or more buckets and treated separately to enable flotation to be carried out effectively

In order to assess the efficiency of this method, the residue of random samples was studied. In the case of densely packed, fibrous peat samples, small portions of the residue were sorted under the microscope to ascertain whether the separation of the insect remains may have been inhibited by the abundance of plant material. Although low numbers of insect fossil fragments were recovered from the residue, these were extremely low and did not affect the overall Minimal Number of Individuals calculated from the floated material.

Remains of Formicidae, Acari, Heteroptera, Diptera, pupae and larvae were also recovered and quantified. The Coleoptera have been identified, primarily by myself, with the aid of Eva Panagiotakopulu. Preliminary work on the identification of

dipterous remains from the site of Akkajärvi has been carried out by Dr Eva Panagiotakopulu at the University of Edinburgh. The extracted beetle fragments were identified primarily through comparison with the Osborne collection stored at Edinburgh University and with reference to the relevant keys. The National Museum of Scotland entomology collection was consulted where the Osborne collection lacked the relevant material. Taxonomy follows Böhme (2005) and Gustafsson (2005). The latter provided the main source of information on current species distributions in Fennoscandia.

It is important that all remains are identified to the lowest taxonomic level possible, preferably to species level, as this will allow for the most specific habitat reconstructions. However, in many cases where a single elytron/ thorax/ head was found in isolation from other diagnostic parts of the insect, identification could only be taken to genus. Identification can be based on gross features such as size and shape, to fine detail such as microsculpture (Robinson 2001). Reference to particular identifications will be made throughout the text, and further information regarding the identification of selected species can be found in Appendix I.

#### **7.4.2 Plant macrofossils**

Plant macrofossils were recovered for Accelerator Mass Spectrometry (AMS)  $^{14}\text{C}$  dating from individual samples whilst sorting for insect fossil remains. The prevalence of seeds, mosses and twigs varied massively between sites/samples; however most of the peat successions showed a move from humified to unhumified material from bottom to top, with approximately the uppermost 30cm rich in well preserved plant macrofossil remains.

#### **7.4.3 Charcoal**

During sorting for insect remains, macroscopic charcoal was removed and counted where found. The sieve size (300 $\mu\text{m}$ ) may filter out some of the smallest charcoal fragments, and the microscopic magnification used during sorting is not enough to detect much of the macroscopic charcoal regularly counted during pollen and soil analysis.

The current literature dealing with dispersal distance of macroscopic charcoal provides variable results depending on a number of factors including particle size, fire intensity, site type and weather conditions (Ohlson and Tryterud 2000; Higuera *et al.* 2005; Tinner *et al.* 2006). Macroscopic charcoal over 0.5 mm in size fragments are rarely found outwith areas which have themselves been burned in a fire (Ohlson and Tryterud 2000; Gardner and Whitlock 2001), although some studies have indicated that large scale fire events may transport macroscopic charcoal over several kilometres (Peters and Higuera 2007; Tinner *et al.* 2006). Only macroscopic charcoal was considered as it generally reflects fires within a few hundred meters (Ohlson and Tryterud 2000), while microscopic elements may be dispersed over a wider distance (Peters and Higuera 2007). Charcoal was found infrequently, with only one site, Lycksele, having high occurrences of charcoal.

## **7.5 Radiocarbon dating**

Dates were typically taken at intervals throughout the sequence in order to provide a timeframe for interpretation. Material was identified with reference to appropriate keys. Samples were sent to the Scottish Universities Environmental Research Centre (SUERC) laboratories for analyses using Accelerated Mass Spectrometry (AMS). The use of AMS dating enables small fragments of identified material to be isolated, thereby avoiding having to date bulk samples, but this also means that contamination will have a more dramatic effect. The careful removal of all humic acids and rootlets minimises problems of contamination (Nilsson *et al.* 2001). Calibration was carried out using OxCal 4.1 (Bronk Ramsey 2009). Unless otherwise stated, dates are shown in calibrated yr BP and given at the 2  $\sigma$  confidence level.

In the first instance materials with a short life span such as seeds and pine cones were selected for radiocarbon AMS dating. These materials avoid the complications attached to dating materials such as charcoal, which may be much older than the sample. Problems of contamination when dating humic acid were similarly limited by the careful selection of appropriate materials (Shore *et al.* 1995; Nilsson *et al.* 2001). At sites where sufficient quantities of the aforementioned materials were not

recovered, in one instance a *Betula* twig was dated, a short-lived species, avoiding the problem of dating heartwood or long-lived tree species (Bowman 1990). Otherwise *Sphagnum* was selected, as it is a material deemed suitable for dating by Nilsson and others (2001) in their analysis of the accuracy of  $^{14}\text{C}$  dating peat samples in Sweden. These mosses lack roots and therefore the incorporation of old carbon from lower layers is not considered a significant problem (Goslar *et al.* 2005).

It is considered that the reservoir effect is not a problem in peat bog samples where the surface vegetation is in balance with atmospheric  $^{14}\text{C}$  values (Blaauw *et al.* 2004) and therefore sampling of material from bogs should be relatively straight forward. Kilian and others (1995) found that the incorporation of ericaceous rootlets into samples could cause dates to be too old. Bulk sampling increases the risk of incorporating rootlets, charcoal, and transported organic carbon, and is generally considered best to be avoided, with *Sphagnum* dating a much preferred option (Kilian *et al.* 1995, Nilsson *et al.* 2001). However, it has been found that on some occasions bulk samples can produce accurate dating results (Blaauw *et al.* 2004).

Root penetration of surface plants can introduce young carbon to lower layers (Nilsson *et al.* 2001) and the downward flux of dissolved organic carbon has been demonstrated to affect the radiocarbon age of gases, causing few problems for peat dates (Aravena *et al.* 1993; Charman *et al.* 1994). Dating of material from the last few hundred years has been hampered by the significant fluctuations of the calibration curve during this time (Stuiver *et al.* 1998). However, since levels of  $^{14}\text{C}$  peaked significantly due to nuclear weapons testing in the 1950s and 1960s, samples dating to post 1950 AD can easily be identified (Reimer *et al.* 2004).

## **7.6 Interpretation**

Habitat information available in Bugs Coleopteran Ecology Package, or BugsCEP (Buckland and Buckland 2006), was the main source of species information, supplemented by a variety of keys which include habitat descriptions of the species (e.g. Lohse 1964; Freude *et al.* 1964, 1981; Joy 1976; Friday 1988; Nilsson and Holmen 1995; Foster and Friday 2011; Lott and Anderson 2011). Nonetheless, the

habitat information available for many species is incomplete. Furthermore many species are able to exploit a wide range of habitats and cannot be easily pigeonholed into any one specific category. Others are far more restricted, but still found in more than one type of material e.g. *Tachinus marginellus* (F.) which lives in both dung and rotting vegetation (Koch 1989ab).

Modern analogues enable a more complex understanding of the relationship between the faunal assemblage and the surrounding environment. Several studies have been undertaken that strongly support the assertion that the insect fossil assemblage reflects the environment in which it formed (Koivula *et al.* 2004; Kenward 2006; Gustavsson *et al.* 2009a). A study by Koivula and others (2004) investigated beetle assemblages obtained by pitfall trapping across a 60m gradient from forest to farmland in Finland, with 0m being the 'edge'. They found that species associated with open habitats were more rarely found in the forested area than forest species found in the farmland half of the edge.

Kenward's (2006) study of fauna from a variety of modern deposits in Britain found that the assemblages from areas with trees/woodland reflected this environment well, with a high proportion of woodland-associated beetles. Similarly, in a study of modern ground surface samples, from a range of sites with different levels of openness, forest cover and grazing, Gustavsson and others (2009a) found that woodland associated beetles were most common at forest sites, and beetles favouring open conditions were most common at open sites as expected, although were often present in forested habitats. They conclude that forest dwelling species are more strongly confined to woodland localities than species associated with open areas are to exposed habitats. Grazing activity was also reflected in the insect fossil assemblages, particularly in the presence of the dung beetle *Aphodius*. The results help to substantiate the use of insects in landscape reconstructions, showing a clear relationship between beetles with specific ecological niches inhabiting the 'correct' habitat.



Smith and others (2010) conclude that openness and tree cover can be assessed adequately from insect fossil assemblages, based on the results of their modern analogue study, which found that the recovered fauna reflected these aspects of their local environment to a high degree. They found that the proportions of species associated with pasture and dung did not correlate with degree of openness.

Values proposed by Robinson (1991, 2000) of around 20% of woodland taxa representing closed forest conditions, are largely arbitrary and have, until recently, remained questionable in their applicability. However the modern analogue study carried out by Smith and others (2010) find that values of over 20% of woodland fauna have been found occurring in heavily wooded areas, and further suggest values of between 5-15% indicating wood pasture. This provides further substantiation for the values proposed by Robinson, although their results also demonstrate that it is possible to have high values of tree taxa in relatively open woodland. Ultimately these values are interesting to consider, but undue emphasis should not be placed on them during interpretation.

The site catchment area must also be considered, and generally an area of a few hundred metres is considered the likely area represented in the insect record, although this varies with site type and landscape structure (Smith *et al.* 2010).

## **7.7 Mutual Climatic Range**

Insect life cycle and distributions can be severely altered by changes in climate, as the abiotic and biotic factors on which they depend are altered (Bale *et al.* 2002; Jönsson *et al.* 2008). In the face of climate change, insects may respond either by adapting, or by shifting their distribution (Carroll *et al.* 2003; Lange *et al.* 2006). Many of the most mobile beetles will respond to climate change by rapid movement, dispersing to suitable locations (Atkinson *et al.* 1987; Ashworth 2001; Coope 2004).

Based on the knowledge that the distribution of many present day species are climatically controlled, insect fossil assemblages can serve to reconstruct past climates (Atkinson *et al.* 1986). Mutual Climatic Range method is based on the

knowledge that many beetles will migrate in response to climate change (Coope 1978; Atkinson *et al.* 1987; Ashworth 2001).

Beetles with restricted thermal tolerances are commonly found in insect fossil assemblages (Elias 2007). Using the thermal envelope (temperature tolerances) of each of the species in an assemblage, based on modern counterparts, MCR then finds the area of mutual overlap of these tolerances to reconstruct the thermal range for the assemblage as a whole (Atkinson *et al.* 1986; Buckland 2007). TMax is the mean temperature of the warmest month of the year and TMin is the mean temperature for the coldest month. TRange is the difference between the TMax and TMin and therefore acts as an indicator of continentality, calculated as the range between the warmest and coldest months (Atkinson *et al.* 1986). Coope and Lemdahl (1996) suggest that it is not necessary that a species entire geographical range limits are known to allow MCR to be successful.

The BugsMCR software in BugsCEP has been utilised for the purposes of this analysis (Buckland and Buckland 2006; Atkinson *et al.* 1986).

For those species which are dependent upon a certain plant, climate may affect their range through varying the distribution of their host plant (Bale *et al.* 2002; Bentz *et al.* 2010). In particular, herbivorous insects are sensitive to changes in temperature, and close synchrony with their plant host is needed for survival (Bale *et al.* 2002). Phytophagous species are currently not included in the BugsMCR dataset due to the fact that host plant distribution may be the underlying parameter, confusing the methodology somewhat (Atkinson *et al.* 1987; Buckland 2007). However, by developing a fuller understanding of how climate affects individual phytophagous species, their inclusion in the dataset offers the potential for expanding the dataset (Buckland 2007). Predators and scavengers can often respond more quickly to climate change, not being dependent on the spread of a host plant before them (Elias 2007), and it is such beetles that make up the BugsMCR dataset at present (Buckland 2007).

The ability of beetles to colonise new habitats quickly means that they can be more effective in determining the rate and timing of climate changes than reconstructions based on pollen, and this characteristic has led to new understandings of the rapidity of climate change, e.g. at the end of the Devensian (Coope *et al.* 1961).

Difficulties persist, with bias inherent in the computational methods (Elias 2010, 62) and problems in determining the best approach to correcting the estimated MCR values (Bray *et al.* 2006). The influence of microclimate may in some instances be problematic (Andersen 1993), however it is considered that the influence of microclimate is ultimately constrained within the limits of certain macroclimates, therefore substantiating the method (Coope and Lemdahl 1996). In terms of fauna from archaeological deposits, the artificially warm microhabitats that may be created could influence the MCR results and should be undertaken with caution (Buckland 2007, 132).

Rigorous testing of the method has been undertaken, demonstrating its efficacy in reconstructing climate. This testing has included reconstructions based on modern assemblages being checked against the modern climate data (Perry 1986; Atkinson *et al.* 1987; Coope and Lemdahl 1996; Elias *et al.* 1996). These found that the climate estimations based on MCR were in close accordance to the temperatures obtained from nearby meteorological stations. Furthermore, comparison of the palaeomodel with reconstructions based on other proxy data, as is demonstrated by Coope and Lemdahl (1996), has shown close correlation.

## **7.8 Quantitative analysis**

Insect fossil analysis requires a careful qualitative approach to be undertaken, with quantitative analysis used only to explore the data. The presence of one specimen may be highly significant, further substantiating qualitative over quantitative methods. Quantification is by Minimum Number of Individuals (MNI) for each sample. This approach determines the lowest number of individuals that could be represented by the disarticulated fossil remains.

### **7.8.1 Ecological groupings**

Differences in sample sizes/sediment types can lead to differences in abundances of different species between samples. It can be beneficial to categorise the species present into broader ecological groupings e.g. ‘woodland’ and ‘aquatic’ etc., which can help to eliminate this problem and allow a consideration of the changes in habitat types represented over time (e.g. Kenward 1978; Robinson 2000), although these are somewhat subjective.

As the number of species is not necessary equivalent to the proportion of the habitat represented, it can be useful to consider the results on a ‘presence only’ basis. This means that abundance is not taken into account. However, in other circumstances the abundance of certain species may be a strong indicator of the prevalence of a certain niche habitat and abundance values may therefore be considered. The ‘BugsStats’ program in BugsCEP (Buckland and Buckland 2006) enables the construction of graphs displaying the changes in habitat groups visually and can be a useful illustrative tool. Generally, abundance data has been used in this PhD research, displaying the results as a percentage (Abundance weighted; %SumRep).

### **7.8.2 Statistical analysis**

In many respects insect fossil data do not meet the requirements necessary for the rigorous demands of numerical analysis (Perry 1986, 12), with restrictions on sampling and the uncertain nature of the representivity of the data recovered. Nevertheless, if these issues are acknowledged and the possible effects understood, then the application of statistical analysis can be a useful tool in exploring the data.

The use of statistical analysis in palaeoentomology is a relatively recent phenomenon. Perry’s (1986) thesis evaluated the use of multivariate methods in palaeoentomology, considering the justification of such methods and the practical value of such analysis. The ability to summarise highly complex relationships in an easily comprehensible form can greatly aid in the task of interpretation. However, ‘Their use can be sanctioned within palaeoentomology *if, and only if*, they are used as a considered means and not as an end’ (Perry 1986, 39). As such, the use of such

techniques in this PhD is exploratory, enabling patterns that occur in the data to be recognised. Hammer and Harper (2006, 5) warn against the use of complicated quantitative data analysis for the sake of it, emphasising that the simplest methods are often the most effective. Standardisation, which is usually applied where different types of variables are recognised, is not required with insect fossil data as measurements on the variables are of the same type (Perry 1986, 30).

Similarity tests can be useful in highlighting the relationship between samples at a site. Using the Bray-Curtis modified Sørensen's correlation coefficient calculation (the inverse of the Bray-Curtis coefficient of dissimilarity), the similarity of each pair of samples in a matrix is calculated (Buckland 2007, 76). The Bray-Curtis modified Sørensen's coefficient considers abundance data but is not skewed by rare taxa (Krebs 1999, 383), a problem in binary similarity coefficients (Krebs 1999, 379), proving useful in statistical comparisons of insect fossil assemblages (Buckland 2007; 114). As this coefficient is based on abundance, and abundance can be affected by sample size, it is important that this measure be applied only to samples of comparable size. Correlation coefficient calculations based on the Bray-Curtis modified Sørensen's coefficient of similarity (Southwood and Hendersen 1978) were carried out using the BugsCEP 'BugsStats' software (Buckland and Buckland 2006)

Similarity/dissimilarity can also be presented in a dendrogram, showing associations graphically. The Bray-Curtis paired-grouping is a useful coefficient when dealing with raw abundance data (Legendre and Legendre 1998, 265), and the conformity of sample sizes made the Bray-Curtis index an appropriate choice where applied in this research. This is a hierarchical clustering method, whereby the most similar pairs of samples in a matrix are joined to form a cluster, then similar clusters are joined and so on until all samples are joined (Hammer 2011). That data will be 'forced' into clusters (Perry 1986, 32) means that it is important to consider the results with care before placing undue emphasis on the patterns revealed through cluster analysis.

Cluster analysis has been successfully applied to assemblages from the Brigg 'raft', where three groupings were identified, relating to different phases of environmental

changes occurring at the site over time (Perry 1981). Perry (1986) later applied cluster analysis to fauna from Lateglacial deposits in Glanlynau, Wales, finding that the resulting four groupings correlated well with the four groupings previously identified by Coope and Brophy (1972) based on qualitative analysis of the data, showing distinct phases of environmental changes, probably linked to climate. At Stóraborg the numerical methods offered clarity to the complex dataset from this Icelandic farm site (Perry *et al.* 1985).

Ordination of the data can then be undertaken to plot the data objects in such a way that the relationship between them can be seen graphically. Without *a priori* knowledge of the factors governing the samples – e.g. differences in climate or vegetation – the samples are ordered based on species presence. This is termed indirect ordination, and the results may be useful in determining underlying gradients and relationships between samples. (Hammer and Harper 2006, 225).

A range of methods are available, and it is at the discretion of the researcher to decide which is most appropriate. Methods of Correspondence Analysis (CA) and Detrended Correspondence Analysis (DCA) are generally considered more applicable than Principal Component Analysis (PCA) which assumes a linear response (Hammer and Harper 2006, 225), and is best suited to data with normal distribution (Hammer and Harper 2006, 83). Correspondence Analysis has been successfully applied in a number of studies, including by Vickers (2006), who used Correspondence Analysis to explore patterns in the insect fossil assemblages from Stóramörk in Iceland, demonstrating a distinction between the pre- and post-Landnám samples. Some of the problems with CA lie in the fact that outliers may obscure the data, and it is often the case that the samples/taxa at each end are squeezed together as the axis is compressed and an arch effect may be seen (Hammer and Harper 2006, 226). This arch effect is considered to be a mathematical product that does not relate to an underlying trend in the data (Hill and Gauch 1980). Detrended Correspondence Analysis can reduce this effect by applying a series of mathematical calculations, and has been applied successfully to many insect fossil assemblages, becoming the most popular indirect ordination method for ecological data (Hammer and Harper 2006, 226). It was developed by Hill and Gauch (1980) in

order to address the problems with CA. In his PhD thesis, Sadler (1991) uses Detrended Correspondence Analysis to plot groupings revealed by cluster analysis, using statistical analysis to examine the habitats of the Icelandic insect fauna for the first time. He identifies underlying factors determining the clusters, namely moisture, exposure and latitude (Sadler 1991, 124). This in turn allows him to consider that these factors are important in influencing distribution (Sadler 1991). Carrott and Kenward (2001) later used Detrended Canonical Correspondence Analysis to test the groupings identified on the basis of co-occurring taxa, on archaeological deposits at Coppergate, York. Vickers (2006) used DCA to compare the insect faunas of the North Atlantic Islands with those of Lateglacial and Early Holocene sites in the UK and Scandinavia, showing that although distinctions are present, the Scandinavian fossils show more similarity to the North Atlantic modern fauna than do the British fossil fauna.

Detrended Correspondence Analysis with basic Reciprocal Averaging was used in this research. Samples and taxa are positioned in a two dimensional chart in such a way as to maintain as much correspondence between the two as possible (Hammer and Harper 2006). The application of this method, using samples and taxa, was confused by the fact that in several of the insect assemblages, a species may be represented by only a single or few individuals. Furthermore, differences in sample size, consistency and preservation meant that in some circumstances samples were highly variable. To avoid some of the problems associated with this, the species were firstly classed into habitat groups (principally based on the ecological groups defined in BugsCEP), and then calculations were based on presence/absence only, not taking abundance into account. The classification into habitat groups is somewhat subjective. However, the most common habitat groups of each species were identified and where more than one habitat is common, species could be placed in two categories. The program PAST was used for clustering and Detrended Correspondence Analysis. PAST is a comprehensive package designed for use in the fields of palaeontology and ecology (Hammer *et al.* 2001).

Fishers alpha was used to consider diversity, an index recommended for use in insect fossil assemblages by Kenward (1978) and which reflects both the number of species

and the number of individuals. The advantages of this are that it allows a consideration of biodiversity in terms of both richness and evenness, and takes into account both common and rare species (Krebs 1999). Furthermore, this index avoids some of the problems of sample size (Fisher *et al.* 1943). It has more recently been applied as a diversity index on palaeoentomological samples by Whitehouse (2004) from Hatfield Moors.



## 8 Norrheden

### 8.1 Site description

The site of Norrheden (N 64° 52.665, E 17° 0.554), approximately 25km south of Storuman, lies 440 metres asl in an area of flat land typified by extensive wetlands. Several smaller lakes and rivers have developed within this wetland basin, with Lake Yttre Olovssjön to the north and the Fiansjön lakes to the south-east (Figure 8.2), and large lake systems occur in the wider area (Figure 8.1). A coniferous-dominated forest of *Pinus sylvestris*, *Picea abies*, with some lesser inclusions of deciduous species, particularly *Betula pubescens*, constitutes the woodland, prevailing most extensively in the west, while to the north and east raised mires blanket the landscape. Low hills rise in the wider surroundings. The dominant field layer vegetation in the area is *Calluna vulgaris*, *Vaccinium vitis-idaea* and *V. myrtillus*.

Samples were taken from an area of recent peat cutting by Phil Buckland and students at the University of Umeå. From these columns, eight samples were sent to The University of Edinburgh for analysis.

The site has been heavily affected by peat cutting, with several km<sup>2</sup> of the bog so far mined (Figure 8.3). Deep drainage channels cover the length of the bog and several large stockpiles of peat had been left on the margins at the time of sampling. The thick forest of the wider area gives way to a forested bog, typified by a sparse covering of pine and spruce trees, with the occasional birch and a *Calluna*-rich ground layer in the immediate surroundings of the cut-over area. *Betula nana* has become established in the margins. On the cut-over surface itself only a few patchy areas of vegetation occur, mainly on the edges of the cut ditches, consisting primarily of grasses/sedges (Figure 8.2). A few shallow pools of water remain on the rapidly drying surface.

Archaeological remains are absent from the near vicinity. The shores of the major lakes in the area are littered with prehistoric settlements, as are some of the smaller lakes (Riksantikvarieämbetet 2012). The map in Figure 8.1 identifies isolated archaeological features, probably prehistoric, within the immediate surroundings

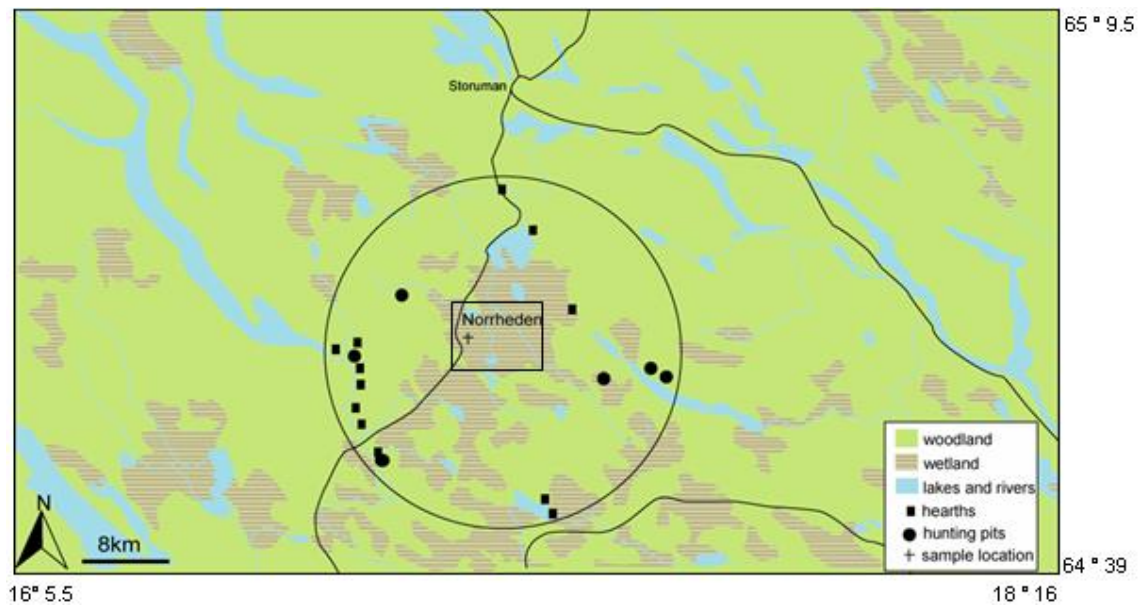
however extensive prehistoric remains litter the shores of the major lakes farther afield. It is possible that other early sites have been masked by bog growth.

It is estimated land uplift is currently occurring at a rate of around 6-7mm per year that in the Norrheden area (Ågren and Svensson 2006). The rate of uplift since deglaciation has been highly variable across northern Sweden, and has slowed since the Early Holocene (Lindén *et al.* 2006; Berglund 2011). Norrheden lies within the area considered by Granlund (1943) to be part of the uplift centre. Changes in landscape dynamics will have played a part in altering the environment around Norrheden since deglaciation, altering the flora and fauna as changes in elevation, topography, hydrology and climate occurred. Today Norrheden is situated at an elevation of 440m asl, approximately 200km from the coast. During the Mid-Holocene Norrheden would have been closer to the coast, and the elevation would have been lower, with a shore displacement (RSL) curve from Norrbotten showing that around 8000 BP the highest shoreline was approximately 80 m asl (Lindén *et al.* 2006). Lake tilting has occurred in the northern interior of Sweden as a result of the higher rate of uplift in the coastal regions compared with that of the interior zone (Bergman *et al.* 2003). In the area around Arjeplog, Bergman and others (2003) estimate the value of the tilting gradient c. 8500 BP to have been 1.0m/km. This has resulted in differential uplift across lake systems in the interior north, changing water-levels and outlets.

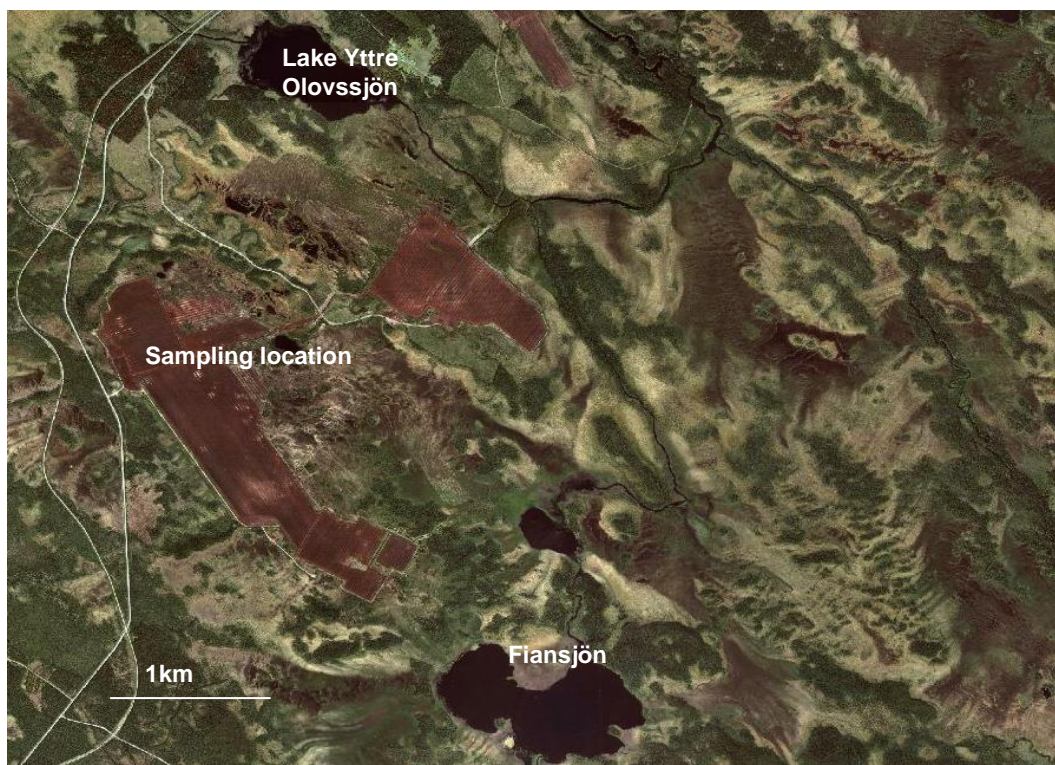
Kullman (1999) suggest that land uplift has been an important control on climate in northernmost Sweden, with approximately 20% of the summer temperature decline to current temperatures from the Early Holocene being connected with this. Mean July temperatures of around 12-14°C and mean January temperatures of around -12 to -14 °C occur in the area today. Granite is the dominant bedrock, and a fine-medium grained till underlies the peat (Fredén 1994).

Sampling from this site was undertaken in order to investigate landscape dynamics in a natural woodland before human impact, and the site offers the opportunity to consider Mid-Holocene climate change and natural disturbances. This natural base-

line will enable the environmental changes from Late Holocene sites with indications of human settlement to be better understood.



**Figure 8.1** Map showing the landscape around Norrheden. Archaeological features of possible prehistoric nature within a radius of approximately 12km of the site have been included (circle shows boundary of 12km radius). A satellite image of the area marked by the rectangle can be seen in Figure 8.2.



**Figure 8.2** Satellite image of the sampling area, showing the extent of peat cutting. The area is indicated in Figure 8.1.



**Figure 8.3** The sampled ditch, showing the restricted vegetation occurring within the ditch, and the grey clay-peat boundary used as the datum. Photograph by the author.

## **8.2 Sampling**

Recent extraction of peat from the site exposed sections suitable for environmental sampling, the grey clay-peat boundary between humified peat and underlying sandy till providing an appropriate datum (Figure 8.3 and Figure 8.4). A series of parallel columns were extracted from above and below this datum.

Two parallel samples were taken from directly below the datum (0- 8cm: Samples 2a and 2b) and directly below this a single sample was recovered at 8-13cm (Sample 1). Three parallel samples were taken from directly above the datum (0-6cm: Samples 3a, 3b and 3c). Another section of peat was sampled above the datum at 15-21cm, where two parallel samples were taken (Samples 4a and 4b). It is not known why there is a gap between the samples at 6-15cm, although insufficient preservation conditions may be assumed. Samples were each approximately 1-2 litres in size, however as parallel samples were taken the bulk for each of the studied assemblages totalled approximately 4 litres.

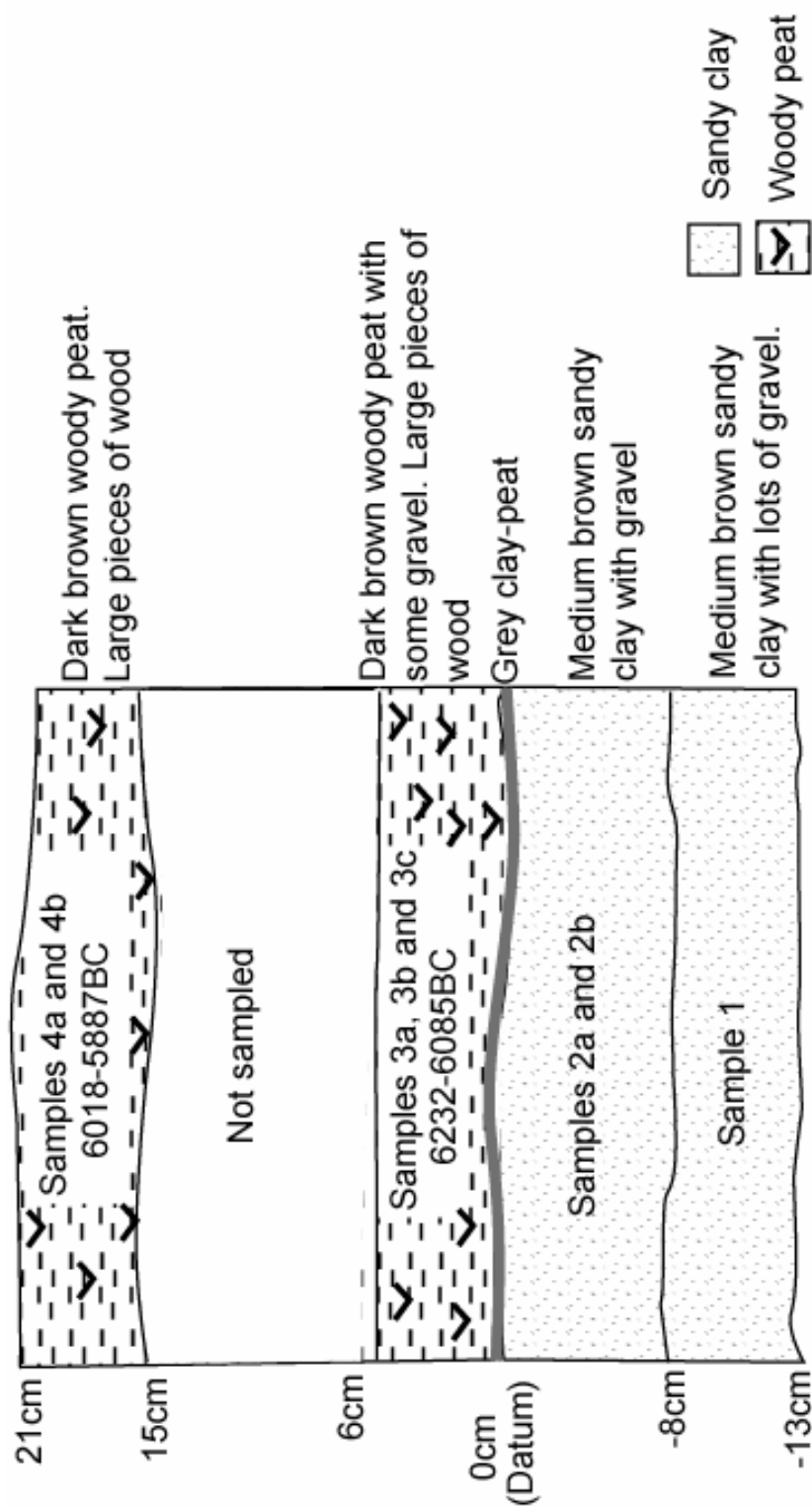


Figure 8.4 Soil profile with radiocarbon dates.



### 8.3 Dating

From Sample 4a *Betula* seeds were dated to  $7070 \pm 35$ , calibrated to 7968-7837 BP, and seeds of *Pinus sylvestris* from Sample 3a returned a radiocarbon date of  $7315 \pm 30$ , which calibrate to 8182-8035 BP. Unfortunately no dates are available from the samples below the datum, however it is apparent that these samples are pre 8182 BP.

Depth	Material dated	Uncalibrated date (BP)	Calibrated age with 95.4% probability ( $2\sigma$ )	Lab Code
15-21cm	Seeds: <i>Betula</i> sp.	$7070 \pm 35$	7968-7837 BP	SUERC-34070 (GU-23799)
0-6cm	Seeds: <i>Pinus</i> sp.	$7315 \pm 30$	8182-8035 BP	SUERC-34158 (GU-23798)

**Table 8.1** Radiocarbon dating results from Norrheden.

### 8.4 Preservation

There was a complete absence of insect fossil remains in Sample 1 (8-13cm) with the coarse sandy/gritty clay, which proved unsuitable for the preservation of delicate remains. Apart from this, preservation of the fauna was good and despite the small size the samples were rich in beetle remains.

### 8.5 Results

Minimum Number of Individuals (MNI) were calculated for each separate sample. MNI counts were then calculated using a combination of the insect fossil counts from the same depths in each of columns, i.e. two samples from 0-8cm (Samples 2a and 2b), three samples from 0-6cm (3a, 3b and 3c) and two samples from 15-21cm (4a and 4b).

#### 8.5.1 Phase I (0-8cm: Samples 2a and b)

The samples from 0-8cm beneath the datum (Samples 2a and 2b) held numerous beetles found in woodland environments, which included species feeding on trees

and within damp, mouldy leaf litter. Tree-dependent scolytids include *Tomicus piniperda* (L.), indicating the presence of pine or spruce trees where hibernation, breeding and feeding take place (Salonen *et al.* 1968; Lekander *et al.* 1977; Koch 1992). This species is commonly found on weakened and dead trees (Lekander *et al.* 1977; Koch 1992).

The presence of deciduous trees is indicated by *Orchesia* sp. which feeds in the fungal-infested parts of trees and dead wood (Palm 1959). They are usually associated with ancient deciduous woodlands (Alexander 1994). *Dorytomus* species are most frequent on *Populus* and *Salix* spp., often growing in quite wet areas (Hyman 1992). The weevil *Phyllobius maculicornis* Germ. is often found feeding upon young trees and shrubs (Austarå *et al.* 1984; Palm 1996; Morris 1997). The adults and larvae of *Anoplus plantaris* (Naezen) are partial to *Betula* and *Alnus* growing in light patches of woodland (Böcher 1995).

Foul and rotting material attracts *Sericoderus lateralis* (Gyll.), which exploits all kinds of mouldy substrates, from floodplains and woodland margins (Koch 1989ab), and individuals of this species were found in Samples 2a and 2b. Numbers of *Tachinus marginellus* (F.) peak in this sample and are accompanied by *Tachinus rufipes* (L.), a species which utilises herbivore dung, decaying plant substances and fungi (Harde 1984; Koch 1989ab). *Megasternum obscurum* (Marsham) is similarly characteristic of wet litter habitats.

Most species of *Sepedophilus* can be found in association with rotting and mouldy wood (Koch 1989ab; Alexander 1994), whilst some species are adapted to grass tussocks and mosses in bogs and meadows (Koch 1989ab; Duff 1993). *Corticaria* sp feed in wood mould and decomposing plant matter, some species occurring in forested environments (Koch 1989ab; Hyman 1994).

The representation of aquatic fauna is low in comparison with the following samples and numbers of *Oxytelus fulvipes* Er., high in all other samples, are at their lowest here. The wetland and leaf litter species include *Syntomium aeneum* (Müll.) which

has been recorded in the damp leaf litter and mosses accumulating beneath trees and in *Alnus* carr (Steel 1963; Koch 1989ab). *Arpedium quadrum* (Grav.) is found throughout Sweden and appears to be affiliated with damp areas of vegetation in heaths, meadows and woodlands, where it can be found amongst accumulating leaf litter (Brundin 1934; Backlund 1945).

*Acrulia inflata* (Gyll.) depends upon mouldy and rotting twigs, bark and leaves, and the fungi growing on trees (Palm 1959; Duff 1993). Koch (1989ab) records it primarily from deciduous woodlands, associated with *Fagus* and Brundin (1934) records it on dead *Betula* and beneath the bark of *Salix*. *Olophrum consimile* (Gyll.) is found amongst vegetation in damp habitats, meadows, bogs and beneath *Salix* and *Alnus*, often on the banks of streams and lakes (Campbell 1983; Böcher 1995). Both are present in low numbers in Samples 2a and 2b.

*Anthophagus* cf. *alpinus* (Payk.) is present, and is generally known from quite open localities where it feeds upon herbaceous vegetation in meadows and woodland margins (Brundin 1934; Koch 1989ab).

### **8.5.2 Phase II (0-6cm: Samples 3a, 3b and 3c)**

The assemblage from 0-6cm above the datum (Samples 3a, 3b and 3c) includes a high number of species found dwelling in old and closed forest environments. Additional scolytids appear. *Pityophthorus* sp. are inhabitants of coniferous woodlands, occurring in the twigs of pine and spruce (Koch 1992; Duff 1993). The sap of *Betula* stumps and occasionally bracket fungi provide suitable substrates for *Rhizophagus parvulus* (Payk.) (Koch 1989ab). Palm (1951) records it from trees affected by fire. It thrives beneath the fungoid bark of deciduous trees, often inhabiting the galleries left by bark beetles of the genera *Hylecoetus* and *Scolytus*, both also recorded from these samples (Palm 1959; Hyman 1992). The identification of *Scolytus* is hindered by the absence of the characteristic head and abdomen (Freude *et al.* 1981). An approximation of size based on the fossil elytra and thorax recovered places this beetle at around 5mm in length, eliminating many of the small members of the genus, of which few reach over 4mm. Separation of the largest species *S. ratzeburgi* and *S. scolytus* remains difficult. The features of the thorax



suggest the specimen is *Scolytus ratzeburgi* Jans. (Spessivtseff 1925; Freude *et al.* 1981) (Figure 8.5). This is the only species of the genus currently found in northern Sweden. It often attacks *Betula* trees, especially those which have been damaged in some way by disturbances such as fire, insect attacks and flooding (Palm 1951, 1959; Lundberg 1984).

Members of the genus *Epuraea* are often found in woodland localities. They are recorded in both coniferous and deciduous woodlands, under bark, in dead wood and sometimes feeding on tree sap and fungi (Alexander 1994; Koch 1989ab). This genus is difficult to identify with confidence to species level in the absence of the often characteristic pronotum. *Hylecoetus dermestoides* (L.) is found in primary, ancient woodland of both coniferous and deciduous tree species (Hickin 1968; Garland 1983; Hyman 1992). It attacks trees which have been damaged in some way, often being found in stumps and dead wood (Horion 1953; Palm 1959; Hyman 1992). The larvae bore deep into the wood where they develop (Horion 1953; Hyman 1992); Palm (1959) notes its abundance in Norrland.

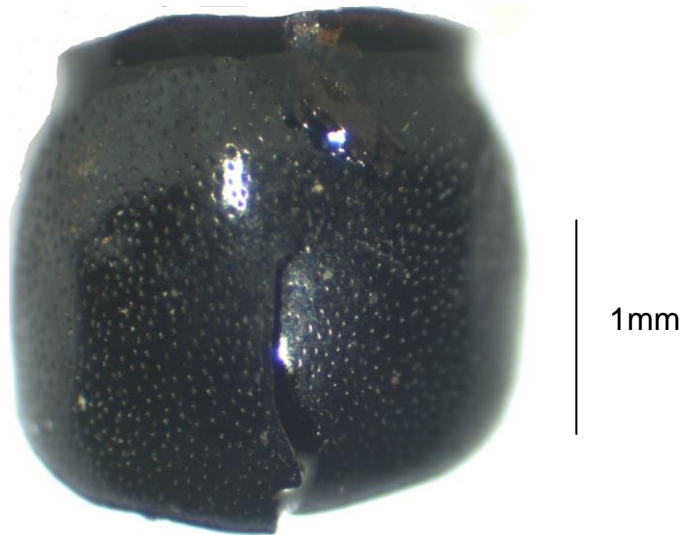
*Deliphrum tectum* (Payk.) is part of the extensive fauna exploiting the accumulated litter layer, and is primarily known from woodland localities in dung and mouldy plant matter (Palm 1951; Koch 1989a). The catopid *Sciodrepoides watsoni* (Spence) has been most frequently recorded from carrion, but also from nests, decomposing organic matter and fungi (Harde 1984; Koch 1989a). *Oxytelus fulvipes* is primarily associated with very wet places, in the mosses, grasses and mouldy leaf-strewn floor of wooded bogs and carrs (Koch 1989a; Hyman 1994) and appears to have an affinity with freshwater (Duff 1993). Palm (1961) has recorded it primarily in damp areas following snow melt, particularly in light areas of carr and woodland, amongst the vegetative litter and also on the margins of rivers and lakes. It was recovered in high numbers throughout the sequence. Palm (1961) records it across Scandinavia, but only as far north as Jämtland in Sweden, and describes it as local and uncommon. However records of it are known in Västerbotten, and from as far north as Norrbotten (Gustavsson 2005). Habitat availability does not appear to pose major restrictions on its distributions, and it may be that temperature is a controlling factor.

The mouldy vegetation detritus in bogs and beneath *Salix* and *Betula* scrub provides a suitable habitat for *Pycnoglypta lurida* (Gyll.) (Brundin 1934; Koch 1989a; Böcher 1995). Common predators in the litter layer of alder and willow stands include the *Olophrum* species, which are often found in the vicinity of streams or waterlogged ground where standing water occurs (Campbell 1983; Koch 1989a; Hyman 1994). In Swedish Lapland, *Acidota crenata* (F.) has been recorded from the vegetated ground layer of birch woodland (Brundin 1934), where moss and leaf litter provide suitable hunting habitat for adults and larvae alike (Campbell 1982). It appears to be attracted to rotting material in damp and shaded localities, in woodland floors and bogs (Larsson and Gíjja 1959; Campbell 1982).

An elytral fragment of *Selatosmus* sp. was recovered. All members of this genus are found within the forest zone, although most are restricted to grassy clearings and heaths within such environments (Laibner 2000). *Patrobus assimilis* is often found in fairly open conditions in bogs and heaths (Lindroth 1985; Koch 1989a). It is also common in woodlands where it dwells in the mosses and detritus of the understory (Lindroth 1985; Koch 1989a). The aquatic *Hydraena britteni* Joy reaches a peak alongside *Ochthebius minimus* (F.). The former species was separated from the similar *H. riparia* based mainly on the characteristics described by Hansen (1987). *H. britteni* is found in both stagnant and running water, in the grassy vegetation of fens and in shaded localities within woodlands (Hansen 1987; Merritt 1995, 2006), while *O. minimus* (F.) again indicates an aquatic environment. Species of *Stenus* are commonly found within the damp ground layer of bog swamps, in wet grassland and woodland (Koch 1989a; Duff 1993).

Carabid species at home in wet bogs and moist, deciduous woodlands include *Agonum gracile* Sturm. *Agonum fuliginosum* (Panz.) and *Loricera pilicornis* (F.). *A. gracile* is found in very wet localities, often in waterlogged *Sphagnum* bogs, where stagnant pools have formed (Lindroth 1945; Koch 1989a), usually amongst the shaded vegetation of grassy tussocks and mossy bolsters (Lindroth 1974; Lott 2003), although also in exposed areas (Lindroth 1945). *A. fuliginosum* has a similar habitat

preference, although deciduous woodland is also a common habitat (Thingstad 1987; Koch 1989a). Shaded deciduous forest provides the niche habitat for *L. pilicornis* (den Boer 1977) where the Collembola dwelling in the detritus layer provide sustenance (Forsythe 1982). It is a hygrophilous species, often in the vicinity of stagnant water (Lindroth 1985; Duff 1993).



**Figure 8.5** *Scolytus cf. ratzeburgi* thorax from Samples 3a, 3b and 3c, Norrheden. Photograph by the author.

### **8.5.3 Phase III (15-21cm: Samples 4a and 4b)**

In Samples 4a and 4b beetles of deciduous woodland are accompanied by species preferring relatively open conditions. The weevil fauna includes *Ellescus bipunctatus* (L.) which occurs in damp deciduous woodlands where it feeds upon *Salix* spp., the larvae developing in catkins (Koch 1992). *Magdalis carbonaria* (L.) is similarly found in deciduous woodlands, particularly on *Betula* spp. where dead wood provides larval nourishment (Hyman 1992). Both species frequent the margins, clearings and other light areas within woodlands (Koch 1992).

A thorax of *Anobium/Hadrobregmus* sp. was recovered from Sample 4b, identifiable by the highly distinctive thorax. This genus of beetles is primarily associated with deciduous woodland, often in dry areas and in dead wood; today some species are also found in worked timber (Palm 1959; Hickin 1968; Koch 1989ab; Hyman 1992). Dead and rotting wood attracts *Cerylon ferrugineum* Steph., which is recorded from

under the rotting and fungoid-infested bark of trees including *Betula*, *Fagus* and *Quercus* (Bullock 1993); it is found throughout the sequence. It has been recorded in ancient woodlands and woodland pastures (Alexander 1994), and Garland (1938) implying exclusivity to primary woodland. Species of *Dienerella*, many of which are now considered synanthropic, originally exploited old woodland habitats where they seek a fungal substrate amongst decaying vegetation, rotting bark and bird's nests (Horion 1961; Koch 1989ab; Krell *et al.* 2005). Palm (1959) records *D. filum* in abundance on rotting wood. Makarova and others (2007) record it from the Russian tundra. It seems that this genus, which originally exploited substrates available in old-growth woodland, such as that prevailing at Norrheden at this time, has come to exploit synanthropic habitats.

*Phosphuga atrata* (L), a snail eating Silphid, is known mainly from woodland localities where it hunts amongst the mosses growing upon rotting wood and bark (Palm 1959).

A rich Staphylinid community, exploiting a ground layer of abundant leaf litter and mosses, is evident from these samples. *Eucnecosum brachypterum* (Grav.) is notably high in number. This species is fairly eurytopic, an inhabitant of grassy heaths, decomposing plant debris, mossy bogs and moist deciduous woodlands (Brundin 1934; Koch 1989a; Campbell 1984). It generally occurs in relatively open areas with abundant ground litter (Brundin 1934; Koch 1989a; Campbell 1984). It has often been recorded in proximity to water, amongst the vegetative debris on the shores of streams and lakes (Brundin 1934; Campbell 1984). *Gymnusa brevicollis* (Payk.) is known from mossy polsters in northern Swedish bogs and *Sphagnum* carpets seem to be a popular habitat for this predatory rove beetle (Larsson and Gíjja 1959; Lindroth *et al.* 1973).

Other Staphylinid taxa include *Lathrobium* spp., *Quedius boops* grp and *Gabrius* sp. These are predominantly wetland species found both in open wet bogs and also in damp woodlands (Koch 1989a; Duff 1993).

Alder-carr is similarly home to *Bryaxis puncticollis* (Denny), dwelling amongst the damp ground layer of mosses and decaying vegetation (Koch 1989a). Larsson and Gíjja (1959) also note it in the sheltered detrital layer beneath old trees (Lindroth *et al.* 1973; Duff 1993).

Water pools choked with leaves, mosses and grasses are favoured by *Hydraena britteni* (Merritt 2006), a species which was recovered in high numbers from these samples. The small dytiscid *Hydroporus* cf. *obscurus* Sturm. is similarly found in vegetated water pools, often in *Sphagnum* dominated bogs (Nilsson and Holmen 1995; Merritt 2006). The moss and mouldy forest floor vegetation provides a habitat for *Agathidium atrum* (Payk.), which is often in waterlogged areas or close to streams in wooded environments (Koch 1989a). *Trechus secalis* Paykull is a deep litter species in damp and shaded areas (Lindroth 1985; Luff 2007). The rove beetle *Erichsonius cinerescens* (Grav.) is in this sample only, a species of swamps and bogs where wet mosses, grassy tussocks and ground litter provide shelter (Backlund 1945; Koch 1989a).

High numbers of *Megasternum obscurum* are present throughout the sequence. It is found within all sorts of decaying matter including rotting vegetation, dung and carrion (Hansen 1987; Koch 1989a), in both exposed fields and closed woodland (Bengtson 1981; Hansen 1987). Similarly, *Tachinus marginellus* (F.) feeds in a range of fetid substrates including herbivore dung and rotting grass, usually in meadows or woodlands (Koch 1989a; Skidmore 1991; Duff 1993), and the species is found throughout the sequence.

Unfortunately the recovered elytral remains of *Longitarsus* were very thin, fragile and fragmented, precluding the possibility of further identification. All members of the genus are found on herbs and grasses in open areas, usually grassy meadows and areas of disturbed ground and very occasionally in light woodland (Koch 1989ab; Hyman 1992; Bullock 1993). In northern Sweden, Brundin (1934) records *Anthophagus* cf. *alpinus* (Payk.) from meadows at high elevations, in birch woodland and willow scrub, on the edges of water and in flowering herbs. Grassy woodland

clearings and meadows are the primary habitat of the click beetle *Ctenicera pectinicornis* (L.), which is often in areas of dry ground (Duff 1993; Laibner 2000).

## **8.6 Landscape Reconstructions**

### **8.6.1 Phase I (>8182 BP)**

Fauna dependent on deciduous trees are present alongside the coniferous-dwelling beetles and signifies a mixed forest during this time. A diverse range of species inhabiting the rotting matter on the forest floor, such as *T. marginellus* and *A. inflata*, indicate a deep and active litter layer as an important habitat within this forested area (Palm 1959; Koch 1989a; Duff 1993).

Coniferous dwelling scolytids, including *T. piniperda*, indicate that pine was a prominent part of the local environment, perhaps with stands of spruce. Recent findings by Parducci and others (2012), who study mitochondrial DNA in *Picea* in Scandinavia, show that local populations of spruce survived in ice-free refugia and spread rapidly with deglaciation, disrupting the previous theory of Late Holocene immigration from the east. Furthermore, investigation of megafossils in the Scandes provides strong evidence for the presence of *Picea* from the Early Holocene (Kullman 2000, 2001, 2002, 2008; Kullman and Kjällgren 2000; Öberg and Kullman 2011). In the Västerbotten region low, sporadic, occurrences of *Picea* pollen have been found from over 8000 years ago (Snowball *et al.* 2002).

Few of the identified taxa are tied exclusively to substantial open spaces, but often reside around woodland margins and clearings. This suggests that natural openings of the canopy occurred but were not extensive, and a closed canopy forest was developing. The indication is of a pine-rich forest with some deciduous trees, probably consisting of birch, willow and alder in lighter and damper areas. The understory of rotting matter hosted an extensive deep litter fauna, while species indicative of open areas are limited, suggesting that closed canopy conditions prevailed in the forest around Norrheden during the period before 8182 BP.

## 8.6.2 Phase II (8182-8035 BP)

The grey clay boundary was used as the datum separating the Phase I and II samples. Peat formation begins above this boundary. Aquatic species are now present, suggesting standing water bodies with vegetated and muddy pools forming an integral part of the woodland. There is an increase in species tied to riparian habitats. Many species are found in very wet places, with pools of standing water, including the aquatic beetles and several hygrophilous Carabid and Staphylinid species. None of the species are restricted to running water, and mainly appear associated with stagnant water bodies, or slow moving water by streams or lakes. It appears that there is a change in the hydrology at the site, with wetter conditions prevailing. This may relate to impedance of drainage as a result of the build-up of a dense mor-humus layer on the forest floor, leading to paludification and bog growth, although a more detailed study of several basal bog localities across the region would be needed to substantiate this hypothesis.

Lake tilting as a result of isostatic rebound in northern Sweden has been demonstrated at the site of Dumpokjauratj in Lapland c. 7300 to 7200 BP (uncal) (Hörnberg *et al.* 2005). The gyttja which characterises the sediments in much of the succession at this site is cut through with a sandy layer, and accompanies a disruption in the dating chronology, interpreted as inflow of older material connected with lake tilting (Hörnberg *et al.* 2005). The timing of the change in hydrology indicated at Norrheden is at odds with the climatically-driven groundwater changes known from Scandinavia at this time (e.g. Hyvärinen and Alhonen 1994; Almquist-Jacobson 1995), but corresponds in time with changes in lake configuration within the region, which may have caused inundation of the site, initiating peat formation. Whether a product of natural paludification, or driven by the effects of lake-tilting, the change in hydrology witnessed in the insect fossil evidence and soil profile from Norrheden demonstrates the formation of bog-growth.

Pine feeding species *T. piniperda* and *Hylastes* sp. remain present, with the addition of *Pityophthorus* sp. A deciduous component of the woodland is reflected in the species assemblage. Species found in mixed woodland now include *R. parvulus*, *H.*

*dermestoides*, and *Epuraea*. Significant numbers of *O. fulvipes* indicate a wet litter layer, possibly in a lake or river-side locality (Palm 1961 Koch 1989a; Duff 1993; Hyman 1994), and occurs alongside the most diverse range of foul dwelling beetles yet seen in the sequence. This sample contains the highest level of species found in rotting and dead wood habitats, and a peak in number of scolytids. Dead wood was a significant part of the woodland environment, with rotting stumps and decaying trees and branches on the forest floor. Old and weak trees comprised a substantial element of the standing trees.

Openings once again provided suitable habitats for *Longitarsus*, *Anthophagus* cf. *alpinus*, *Apion* and *O. nodosus* indicating that exposed areas occurred within the forest, allowing the flowering of herbaceous vegetation. Wetland fauna are abundant, consisting of some fairly eurytopic species of both open heath and also woodland understory such as *P. assimilis* and *E. brachypterum*. These are accompanied by peak numbers of aquatic taxa. Standing water was prevalent, with vegetated and muddy pools forming an integral part of the woodland floor, perhaps within an increasingly boggy environment.

During this phase a mixed coniferous-deciduous forest prevailed, with abundant old and dead wood and a deep and active litter layer, and the area was heavily wooded during the period covered by these samples.

### **8.6.3 Phase III (7968-7837 BP)**

The woodland is dominated by species found in deciduous woodland habitats, with no species specifically tied to coniferous woodland. Indeed, the character of the woodland is *Betula*-dominated forest, with *Alnus* and *Salix* scrub in wetter areas, differing from the preceding samples.

The woodland canopy was substantial but not dense. Some of the tree-dependent species identified are found primarily in light woodlands or woodland clearings and margins, such as *E. bipunctatus* and *M. carbonaria* (Hyman 1992; Koch 1992). Openings within the forest are demonstrated by species which inhabit grassy clearings where the ground flora on which they feed flourishes. Herb-feeding species



of *Apion*, occurring on open areas of ground (Hyman 1992; Koch 1992; Gønget 1997), are at their highest in number in these samples. Open ground dwelling *Longitarsus* are similarly prevalent, and a single individual of *C. pectinicornis* occurs, an elaterid which seeks out exposed areas of ground to feed and breed (Duff 1993; Laibner 2000). Light penetrated the forest floor, allowing growth of herbs and flowers, and open areas existed within the woodland.

Beetles roaming the litter layer are high in number, suggesting that an extensive mat of leaf litter accumulated beneath the tree and shrub canopy. A decaying and mould-ridden detritus layer was host to many species such as *M. obscurum* and *T. marginellus*, attracted to fetid environments (Hansen 1987; Koch 1989a; Duff 1993). Mosses, particularly *Sphagnum*, seem to have formed an important part of the forest floor, providing conditions suitable for *G. brevicollis* and *E. cinerescens* (Backlund 1945; Larsson and Gígja 1959; Lindroth *et al.* 1973; Koch 1989a). The high numbers of aquatics and wetland/bog species indicate that the ground was waterlogged, with large pools of stagnant water, and perhaps small, slow running streams. High numbers of *H. britteni* attest to the shaded conditions within which the aquatic habitats developed (Hansen 1987; Merritt 2006).

*C. ferrugineum* suggests the presence of rotting wood (Bullock 1993) and *Dienerella*, *A. inflata* and *P. atrata* occur in small numbers. These are found on rotting and fungus infested wood (Palm 1959; Duff 1993). Of interest is the absence of bark beetles, a family of insects associated with the primary stages of tree decay (Palm 1959). This assemblage indicates that an accumulation of dead wood on the forest floor was present, although not as extensive as previously seen.

During this phase the environment hosted damp woodland with abundant ground litter and decaying vegetation. Open areas were a permanent feature of the forest—the canopy itself does not seem to have been completely closed over.

## **8.7 Comparison with regional vegetation development**

The fauna from the Norrheden sequence reflects natural forest development during the Mid-Holocene. The forest initially comprised a mixed coniferous-deciduous forest with a damp detritus layer forming in the moss and litter of the forest floor, as evident in the Phase I fauna (> 8182 BP). This forest develops, becoming denser, and pools formed amongst the deep litter of the ground layer. The landscape becomes increasingly dominated by deciduous species and open areas are a more significant part of the landscape structure, as witnessed in the fauna from Phase III (7968-7837 BP). This pattern of vegetation development is also seen in pollen and macrofossil records from northern Sweden.

Pollen and macrofossil evidence from six sites in the Torneträsk area by Barnekow (2000) demonstrate that *Betula* forest characterised the Early Holocene landscape after deglaciation, with pine-birch forest prevailing from c.7800 BP. Evidence from pollen cores at two sites in the Arjeplog area suggests that *Betula* was prominent in the Early Holocene, after which *Pinus* increased from ca. 8000 BP (uncal), developing into a closed pine dominated forest at one site from 7600 BP (uncal) (Hörnberg *et al.* 2005).

Snowball and others (2002) studied varved lake sediments from two sites in Västerbotten, demonstrating once again that by c. 8300 BP pine and birch characterised the forest of the inland north, with alder in the wetter areas. In Västerbotten Barnekow and others (2008) similarly found closed conditions prevailing from c. 8500 BP, with *Pinus*, *Betula* and *Alnus*. *Betula* coming to dominate at the site from c. 7000 BP (Barnekow *et al.* 2008). Engelmark (1996) sees *Betula* gradually increasing in many areas of Umeälven from around 8000 BP (uncal), although not becoming a dominant part of the forest landscape until c. 5000 BP (uncal). Similarly at Norrheden the forest was initially coniferous dominated mixed woodland, with closed conditions prevailing in Phase II (8182-8035 BP). Deciduous trees appear to have become an increasingly important part of the landscape in Phase III (7968-7837 BP).

## **8.8 How open was the forest?**

Disturbances within forest ecosystems foster a dynamic structure in which stands of old and mature trees are juxtaposed with open areas. The prevalence and stability of these open areas differ according to many factors, of which the type and severity of disturbance is one. Some gaps are transitory while others develop a more long-term, and distinct vegetation. This often occurs alongside water-bodies and within wetlands (e.g. Peterken 1996). Indeed, Svenning (2002) concludes that floodplain sites tend to be naturally open, often characterised in the pollen record by herbaceous vegetation of grasslands and meadows, and in the insect fossil record by a prevalence of dung beetles. However, at some floodplain sites substantial indications of forest have been found in the insect fossil record (cf. Dinnin 1997).

The fauna from Norrheden show the dynamism of the forest, indicating different degrees of openness within the natural woodland. In both Phases I and II indications of open spaces are present, but low, suggesting that openings in the forest were perhaps transitory and not extensive. In Phase III the proportion of species of open areas are relatively high and deciduous dwelling beetles increase. *Betula*, being a pioneer taxa, requires light conditions in which to flourish (Hynvanen *et al.* 2010). Shade intolerant alder and willow are also indicated in the insect assemblage, and alongside the aquatic fauna, the wet nature of the area is demonstrated. The canopy of birch woodlands is generally light, encouraging ground vegetation. This is apparent from the insect fossil assemblage in Phase III, which suggests that the canopy was sufficiently open to let light through, encouraging the establishment of herbaceous vegetation.

The wet nature of the site would have increased the vulnerability of trees to toppling by wind, creating continuous spaces and opportunities for the field layer to develop. Peterken (1996) calculates that windthrow in the ash and alder stands which characterise the wet soils of the river floodplain of Białowieża forest in Poland maintains a canopy which is 20-40% open, and the prevalence of standing dead trees is small. Although the beetle taxa for the shrub and herb layer are not extensive in

Phase III, they suggest that the canopy was far from dense. Certainly low but persistent numbers of xerophilous and phytophagous taxa existed.

A comparison with Mid-Holocene beetle assemblages from natural forest sites in Sweden highlights the variable extent of openness across site types. From Mid-Holocene deposits from Stavsåkra and Storasjö in southern Sweden, Olsson and Lemdahl (2009a; 2009b) found an abundance of forest dwelling and saproxylic beetles and few indicators of more exposed areas, indicating a dense woodland. The assemblage includes species found in old and dead wood including *Scolytus ratzeburgi* and *Prostomis mandibularis* (F.) and mould beetles including *Corticaria ferruginea* Marsham. Occurrences of beetles preferring open areas at Storasjö suggest that patchy openings were present in the landscape, although to a lesser extent than in Early Holocene samples, and alongside charcoal and pyrophilic species such as *Agonum bogemanni* (Gyll.), suggests fire was involved in maintaining this landscape structure (Olsson and Lemdahl 2009b).

The only comparable insect faunal assemblage from northern Sweden around the Early-Mid-Holocene is that from Hemavan, approximately 100km northwest of Norrheden (Buckland 2007). Of the 61 species recorded from Hemavan, 24 are found at Norrheden. The samples are dated by correlation with the pollen cores indicating an age range covering roughly the same period as Norrheden in the lower part of the sequence (c. 8025±100 BP (uncal)). The corresponding samples indicate quite a different environment, dominated by wetland fauna and indications of *Salix* scrub in the surroundings. Only a few tree-dependent species are present, and no coniferous woodland beetles were recorded. Similarities exist in the vegetative litter and moss dwelling species of Carabidae and Staphylinidae, however the Hemavan material does not present the diverse fauna of the deep litter layer with foul and decaying vegetation, as seen at Norrheden, with the ‘foul’ element represented by low numbers of *Lathrobium*, *Omalium*, *Philonthus*, *Cercyon* and *Aleocharinae*, and a single specimen of *Tachinus rufipes*. This site is located at 450m asl, in the Alpine zone of Sweden. The differences in altitude, topography and climate between the areas have clearly led to highly variable vegetation development, with the landscape

at Hemavan not developing into the same closed canopy conditions seen at Norrheden. Indeed, evidence that a sub-alpine birch forest emerged in the area around Hemavan from 6000 BP has been found by Kullman (1992).

## **8.9 Disturbances in the Holocene forest**

### **8.9.1 Grazing**

Many beetle species are feeders on, or predators in herbivore dung. Dung beetles of the genus *Aphodius* and *Geotrupes* are prevalent throughout Scandinavia today, and have featured in the fossil assemblages from a range of sites in Sweden, including both natural successions and archaeological deposits throughout the Mid-Holocene period (Gaillard and Lemdahl 1994; Buckland 2007; Olsson and Lemdahl 2009a, 2009b).

No dung beetles were found at Norrheden. Species of *Megasternum obscurum*, *Tachinus rufipes* and *T. marginellus*, found at Norrheden, may exploit herbivore dung (Backlund 1945; Hansen 1987; Koch 1989a; Duff 1993). However, none are restricted solely to this habitat and they are commonly found in other decaying substrates (Backlund 1945; Hansen 1987; Koch 1989a; Duff 1993), which are analogous to herbivore dung.

From Stavsåkra, southern Sweden, samples have produced coprophagous and coprophilous species, but similarly to Norrheden, no species restricted only to dung were found during the period c. 8250-3350 BP (Olsson and Lemdahl 2009a). At the neighbouring site of Storasjö, Olsson and Lemdahl (2009b) once again noted a lack of dung beetles from 7550-900 BC (c. 9500-2850 BP). At Hemavan in northern Sweden several species are found in foul vegetative matter, and possibly in dung (Buckland 2007); these include *Tachinus rufipes*, and, similarly to the Norrheden fauna, no obligate dung beetles were found.

In the absence of species more explicitly associated with dung, the discussed species from Norrheden are considered to have depended primarily on the extensive rotting matter of the deep litter layer on the woodland floor.

### **8.9.2 Fire**

Evidence for a fire-affected landscape at Norrheden is similarly lacking. No charcoal was recovered from the succession and no pyrophilous species were found. Palaeoecological evidence from around the close of the boreal and into the Atlantic period suggests that fire frequency may have been low (Pitkänen *et al.* 2002). Greisman and Gaillard (2009) suggest that low fire activity in Stavsåkra around 6500 BC may equate to the 8.2 kyr event of increased precipitation and decreasing temperatures. Also at Stavsåkra, the insect fossil evidence shows that during the period 6450-4200 BC (c. 8400-6150 BP), fire-related species are present in low number (Olsson and Lemdahl 2009a). At Storasjö a complete absence of pyrophilous beetles is found in the Mid-Holocene samples, with macroscopic charcoal very low during the period c. 8150-7575 BP (Olsson and Lemdahl 2009b; Olsson *et al.* 2009). At both sites, evidence for fire in the insect fossil record is higher during the Early and Late Holocene than in the Mid-Holocene. From such evidence it is clear that periods of low fire frequency may have been commonplace in the forests of the Mid-Holocene in Sweden, and that climate has been a significant factor in determining fire frequency and intensity during the Early-Mid-Holocene, with no direct indication of humans in the landscape. A few peaks in the charcoal fragments from a lake sediment core at Makkassjön in northern Sweden during a period around the Early-Mid-Holocene were observed by Korsman and Segerström (1998), however it is only in the last few thousand years that charcoal becomes more prevalent, once again demonstrating the low incidence of fire before humans entered the landscape.

### **8.10 Climate inferences from the insect fossil assemblages**

Closed forest dominates in Phases I and II. In Phase II a coniferous-dominated forest is observed with extensive old, dead wood and abundant decaying vegetation, with limited open spaces, indicating the culmination of closed forest in the investigated period. This occurs c. 8108 BP. Following this, the evidence from Phase III suggests the spread of deciduous woodland and lighter conditions within the woodland, in the period around 7903 BP.

During this period a pattern of colder temperatures, followed by warming, has been demonstrated in the palaeoecological data throughout northern Scandinavia (Barnekow 2000; Korhola *et al.* 2000; Rosén *et al.* 2001; Seppä and Birks 2001; Snowball *et al.* 2002). A cooling event has been found in diatom evidence from Finnish Lapland (Korhola *et al.* 2000), in a cold snap occurring c. 8300 BP, followed by a rapidly ameliorating climate for several centuries. Rosén and others (2001) suggest a cooling phase occurring c. 8500 BP in the diatom and chironomid-evidence, followed by ameliorating temperatures occurring c. 8000 BP. At the Västerbotten sites, Snowball and others (2002) suggest that the changes seen in total pollen influx and mineral-matter accumulation c. 6000-5700 BC (uncalibrated) may be equivalent to the widespread cold event. Following this, there is evidence in the regional palaeoecological data to suggest that the climate warmed rapidly. Increased deciduous tree species observed in the pollen and macrofossil record following this cold period are considered by Snowball and others (2002) as a response to rapidly ameliorating temperatures. Occurrences of *Quercus*, *Ulmus* and *Tilia* in the pollen record c. 7000 BP reflect the local presence of such species (Barnekow *et al.* 2008). However, based on the finding of macrofossil evidence of trees at high elevations in the northern Scandes, and considering isostatic uplift, Kullman (1999) estimated that in 8500 BP, summers were approximately 2.4°C warmer than present, within a continental climatic regime.

The move from closed pine forest to more open deciduous woodland at Norrheden coincides with a regime of colder temperatures from c. 8000 BP, moving towards warmer temperatures in the following centuries. This pattern of vegetation development has been observed elsewhere in the region during this period, as discussed. Overall, the evidence suggests that the environmental changes seen at Norrheden may have been influenced by regional climatic changes.

### **8.10.1 Mutual climatic range**

When the land rebounded as a result of the retreating ice-sheet, changes in altitude in the Early Holocene were rapid, and this has continued to affect the elevation and

topography of the study area to the present day (Eronen 2005, 32; Lindén *et al.* 2006; Berglund 2011). This process will have affected temperature, with increasing altitude generally decreasing temperature in the troposphere (Shipman *et al.* 2012, 545).

Work carried out on modern populations of insects, particularly focusing on beetles, lends support to the assertion by Coope (1978) based on the fossil record, that Coleoptera adapt to climate change not through physiological adaptations but in altering their distribution (Atkinson *et al.* 1987; Butterfield 1996; Carroll *et al.* 2003). Butterfield (1996) studied southern beetle assemblages at sites above 400m asl in northern England over an altitudinal gradient with a mean annual temperature difference between extreme sites of 3-5°C. He found that the species assemblages were almost entirely different between the extreme sites, and furthermore, that the studied carabids did not alter their life-cycle strategies as a method of adaptation to different temperatures. In British Columbia the distribution both across latitude, and elevation, of mountain pine beetles, is determined by climate rather than the range of the tree host (Carroll *et al.* 2003). This study shows that climate change since the 1970s has enabled the expansion of the pine beetles into areas with previously unsuitable climatic regimes (Carroll *et al.* 2003). This indicates that beetles may extend their range in response to climate, and that altitude is an important determining factor.

That temperature is a significant factor determining many species' geographic ranges highlights their potential in revealing climatic information. This is the premise on which the Mutual Climatic Range method has been built (see section 7.7). MCR has been applied to the Norrheden material to test whether changes in climate at this site can be estimated using this method.

In the following graphs and tables, TMax serves as an index of the mean temperature of the warmest month, TMin for mean winter temperature and TRange as an indicator of continentality, calculated as the range between the warmest and coldest months (Atkinson *et al.* 1986). The overlap of the thermal envelopes on the resulting graph demonstrates the range of temperatures in which all of the species can survive



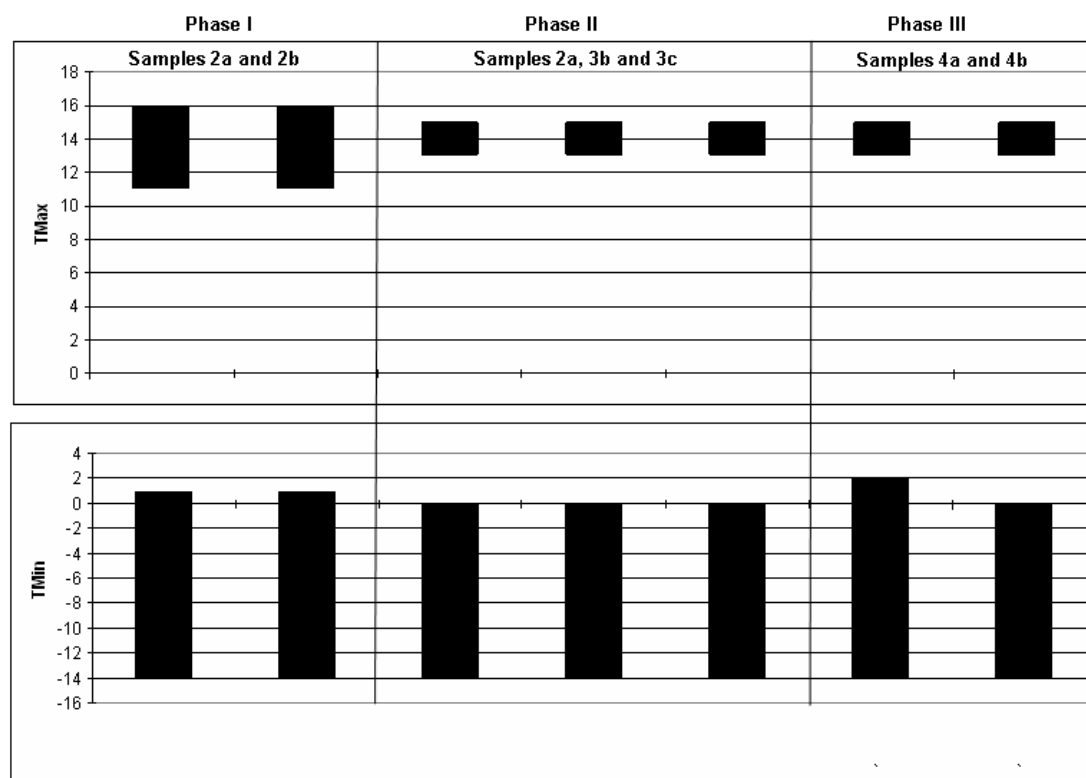
(Atkinson *et al.* 1986). The ideal 100% overlap is met in all of the samples from Norrheden (Table 8.2). This means that all the species in the sample can survive within this set of temperature values.

The TMin temperature ranges are broad, however *Hydraena britteni*, found in all samples, requires a minimum winter temperature of -14°C (Table 8.3). In northern Sweden today, -14°C is the average temperature of the coldest month in inland areas above 65°N (Figure 8.7).

*Agonum gracile*, with a TMaxLo of 13°C (lower limit of reconstructed mean temperature of the warmest month), was found in Samples 3 and 4 (Table 8.4). This species was also recorded at Hemavan, in samples dating to approximately c. 5600 BP (Buckland 2007). Also in these samples is *Olophrum rotundicolle*, with a TMaxHi of 15°C (upper limit of reconstructed mean temperature of the warmest month) (Table 8.5). July temperatures of 13-15°C are found along the coast, extending further inland in certain localities (Figure 8.8).

Results of MCR analysis on the Norrheden samples are displayed in Figure 8.6 and Table 8.2. The data do not indicate any major temperature changes over the three phases studied. This is partly restricted by the limited number of MCR species able to be used, and the broad thermal ranges of those species whose tolerances are known. The thermal tolerances for many species are unknown, with 436 species currently comprising the BugsMCR dataset (Buckland and Buckland 2006). Furthermore, the climatic envelopes of many species remain coarse (Buckland and Buckland 2006). Only MCR species are used, i.e. species whose tolerances are known, which is limiting, and currently only predator and scavenger species are used as the distribution of phytophagous insects may be a product of their host plants' ecological specifications, rather than climate (Atkinson *et al.* 1987; Buckland 2007). The low number of species used in the climatic reconstruction limits the ability to draw fine-grained climatic information using MCR. A fuller description of the method and a discussion of its limitations can be found in section 7.7. Consideration

of selected species with more restricted thermal envelopes indicates that temperatures did not significantly exceed -14°C in winter and 13-15°C in summer, a temperature regime not much different from that of the study area today.



**Figure 8.6** BugsMCR temperature reconstructions.

Sample	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi	NSPEC	Overlap
S2a	11	16	-14	1	15	28	6	100
S2b	11	16	-14	1	15	28	7	100
S3a	13	15	-14	0	15	27	9	100
S3b	13	15	-14	0	15	27	12	100
S3c	13	15	-14	0	15	27	9	100
S4a	13	15	-14	2	13	27	11	100
S4b	13	15	-14	0	15	27	13	100

**Table 8.2** Results of BugsMCR analysis.

Species	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi
<i>Hydraena britteni</i>	11	19	-14	7	8	28

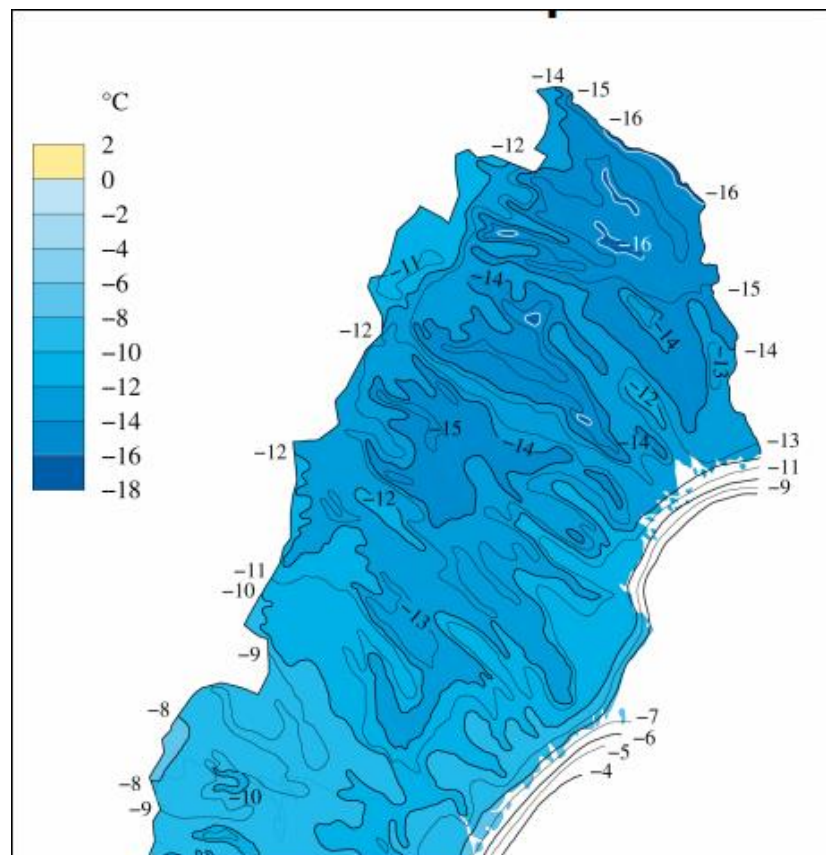
**Table 8.3** Temperature envelope of *Hydraena britteni* (all sampes).

Species	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi
<i>Agonum gracile</i>	13	28	-46	10	10	60

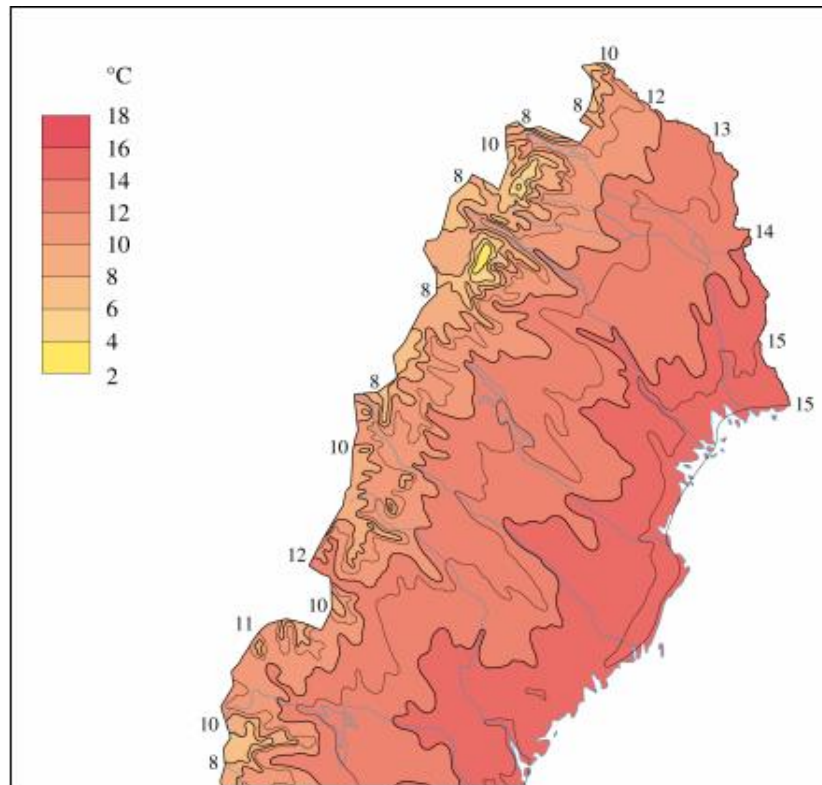
**Table 8.4** Temperature envelope of *Agonum gracile* (Samples 3 and 4).

Species	TMaxLo	TMaxHi	TMinLo	TMinHi	TRangeLo	TRangeHi
<i>Olophrum rotundicolle</i>	9	15	-21	2	13	30

**Table 8.5** Temperature envelope of *Olophrum rotundicolle* (Samples 3 and 4).



**Figure 8.7** Average temperatures for January (1961 -1990) in northern Sweden (SMHI 2009e).



**Figure 8.8** Average temperatures for July (1961-1990) in northern Sweden (SMHI 2009f).

### **8.11 Comparison of parallel samples**

The extraction of material from adjacent samples at Norrheden allows an interesting and rare analysis of the similarities/differences in insect fossil assemblages from parallel sections. Several methods have been used in order to explore statistically the horizontal relationship between samples. Firstly, similarity tests using the Bray-Curtis modified Sørensen's coefficient were carried out in order to compare the similarity of samples at the same depth. Using the correlation coefficient calculation, the similarity of each pair of samples in a matrix is calculated. The Bray-Curtis modified Sørensen's coefficient considers abundance data but is not skewed by rare taxa, proving useful in statistical comparisons of insect fossil assemblages (Buckland 2007, 114).

Results of the Bray-Curtis modified Sørensen's coefficient calculations for each set of samples are displayed in Table 8.7 and Table 8.8. Values closer to 1 represent the most similarity between samples. The results show significant similarity between the

investigated samples of the same depth, with values of 0.6 or higher. This provides strong evidence to suggest that the usual method employed in sampling for insect fossil remains, where a single sample is taken from each depth, is representative and that variations in assemblages over small, horizontal distances are minimal.

Cluster analysis based on the Bray-Curtis paired-grouping (Figure 8.9) represents this information in a dendrogram, showing clearly the associations between the three groups of samples from the same depths.

	S2a	S2b
S2a		
S2b	0.6375	

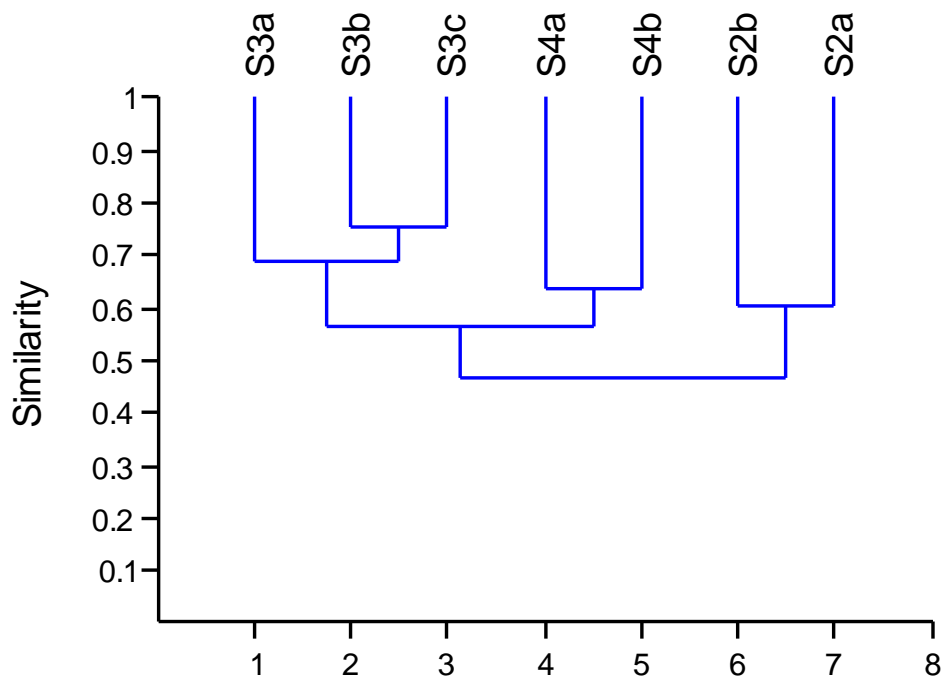
**Table 8.6** Adjacent samples from a depth of 0-8cm.

	S3a	S3b	S3c
S3a			
S3b	0.712803		
S3c	0.681319	0.767606	

**Table 8.7** Adjacent samples from a depth of 15-21cm.

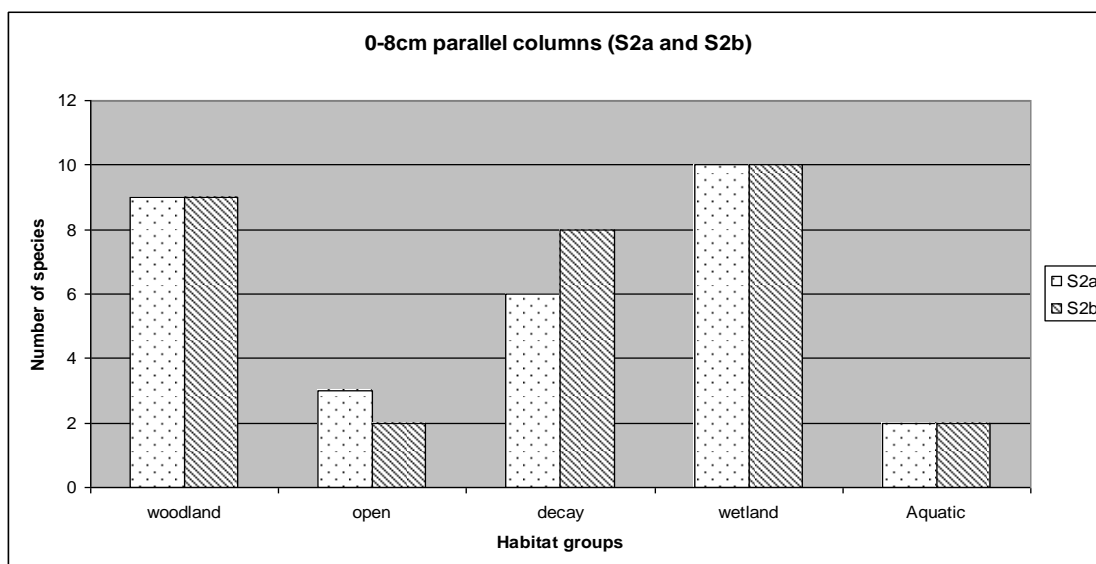
	S4a	S4b
S4a		
S4b	0.632911	

**Table 8.8** Adjacent samples from a depth of 0-6cm.

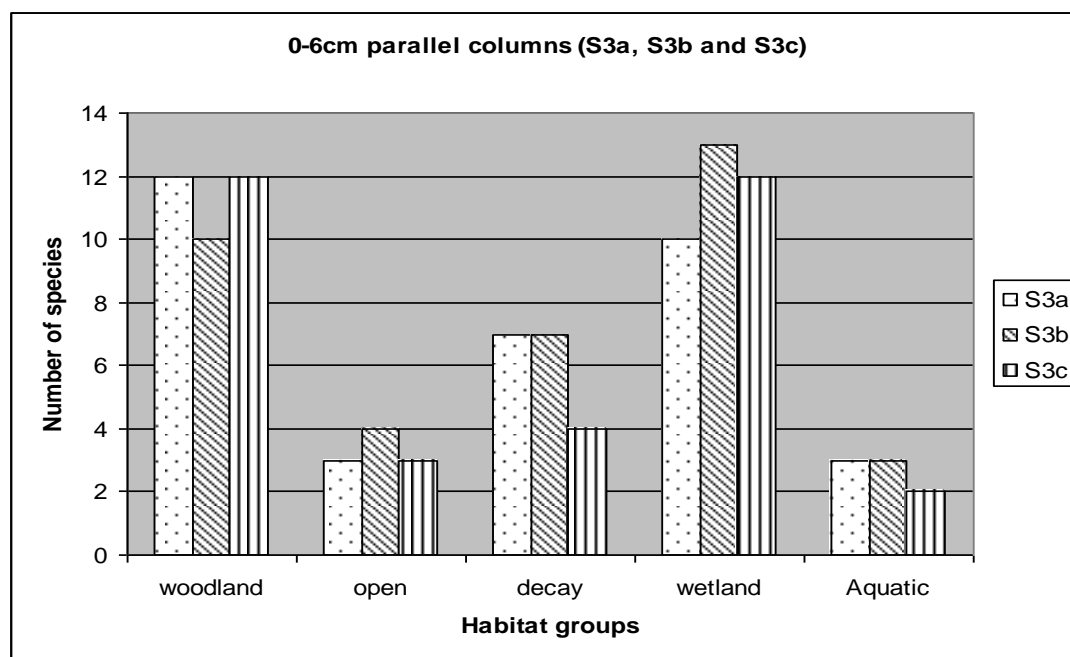


**Figure 8.9** Cluster analysis using Bray-Curtis paired groupings (abundance data- number of individuals).

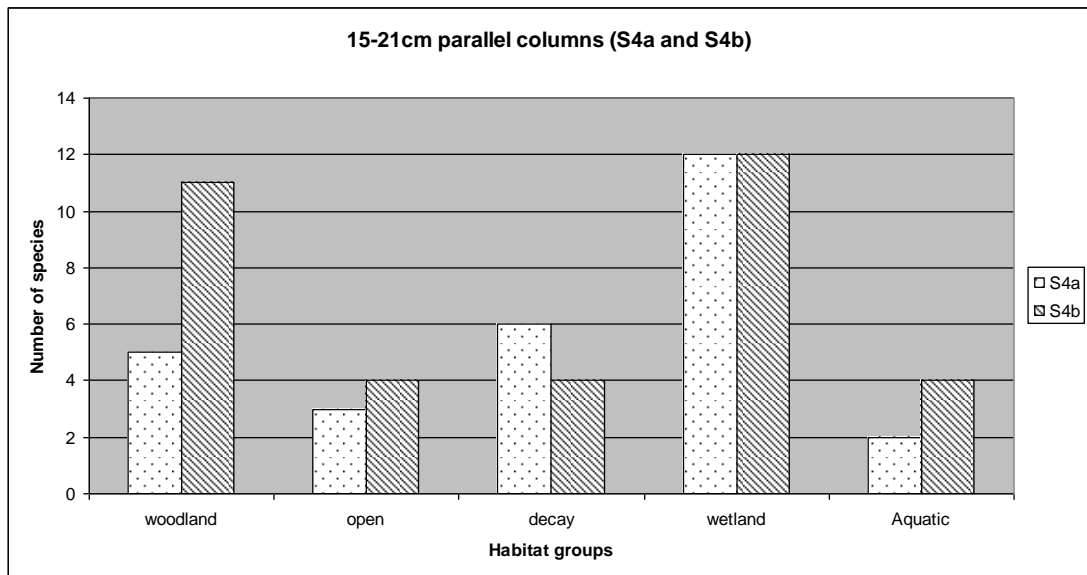
Further comparison was carried out between the represented habitat groups in samples of the same depth. In order to assess the similarity between the ecological groupings, graphs were created comparing the proportions of specific habitats represented in the individual samples from the same depth. In Figure 8.10 the habitat groups of the two parallel samples at 0-8cm (Samples 2a and 2b) are represented. Both display similar proportions of species associated with the given habitat. This is similarly demonstrated in the three samples from 0-6cm (Figure 8.11). The only notable discrepancy occurs in the woodland and aquatic categories of the 15-21cm samples, with Sample 4a containing almost half the number of indicator species of Sample 4b (Figure 8.12). Overall, the parallel columns display remarkable similarity, showing that discrepancies between adjacent columns are not significant. This evidence indicates that parallel samples from the same depth have such a degree of similarity in species composition that interpretation based on either would be the same. This provides strong evidence that samples are representative over a small area. It would be interesting to see if the results were replicated over a larger area.



**Figure 8.10** Comparison of habitat groups represented in parallel columns from 0-8cm. Species may be included in more than one ecological group. The groups are defined as: *Woodland* - species tied specifically to trees, and ground beetles generally found in woodland environments e.g. in leaf litter; *Open* – species found in open areas, woodland clearings and margins, and herbaceous vegetation; *Decay*- species found in dead and rotting wood, and in decaying vegetation; *Wetland* – species found in wetland habitats; *Aquatic* – species found specifically in water bodies.



**Figure 8.11** Comparison of habitat groups represented in parallel columns at 0-6cm.



**Figure 8.12** Comparison of habitat groups represented in parallel columns at 15-21cm.

The palaeoecological evidence from Norrheden has allowed aspects of past vegetation development, natural disturbances and climate within the Mid-Holocene boreal forest of northern Sweden to be explored and enabled some of the hypotheses set out at the outset of this research to be tested. Furthermore, it establishes a means by which to compare the impacts of later human activity on the landscape. The following chapters will, in turn, present evidence from five different sites, each of which contain evidence of human activity.



Sample	2a	2b	3a	3b	3c	4a	4b
Sample depth (cm)	0-8	0-8	0-6	0-6	0-6	15-21	15-21
	(below	(below	(above	(above	(above	(above	(above
Radiocarbon age	datum)	datum)	datum)	datum)	datum)	datum)	datum)
			8182- 8035BP			7968- 7837BP	
Faunal list							
Carabidae							
<i>Loricera pilicornis</i> (F.)						1	
<i>Trechus secalis</i> Paykull							4
<i>Bembidion</i> sp.							1
<i>Patrobus assimilis</i> Chaud.				4			
<i>Patrobus</i> sp.	1		1				1
<i>Pterostichus</i>				1			
<i>strenuus/diligens</i> (Panz.)/(Sturm)							
<i>Agonum gracile</i> Sturm			1	2	1	2	7
<i>Agonum fuliginosum</i> (Panz.)				2	1	2	4
Dytiscidae							
<i>Hydroporus</i> cf. <i>obscurus</i> Sturm							2
<i>Hydroporus</i> sp.	2	2	2	2	3	1	
Hydraenidae							
<i>Hydraena britteni</i> Joy	1	2	9	12	15	16	13
<i>Ochthebius minimus</i> (F.)			1	6			1
Hydrophilidae							
<i>Megasternum obscurum</i> (Marshall)	6	5	8	10	9	16	7
<i>Enochrus</i> sp.							1
Silphidae							
<i>Phosphuga atrata</i> (L.)							1
Catopidae							
<i>Sciodrepoides watsoni</i> (Spence)		1	1			1	
Leiodidae							
<i>Agathidium atrum</i> (Payk.)						1	

Othroperidae							
<i>Sericoderus lateralis</i> (Gyll.)	1	1	3	1			
Staphylinidae							
<i>Acrulia inflata</i> (Gyll.)		2	1	1			1
<i>Pycnoglypta lurida</i> (Gyll.)	3	4	8	8	8		1
<i>Deliphrum tectum</i> (Payk.)			1				
<i>Olophrum consimile</i> (Gyll.)	1	1	2	1	7	5	5
<i>Olophrum rotundicolle</i> (Sahl.)			5	7	1	2	1
<i>Arpedium quadrum</i> (Grav.)		2			1		
<i>Eucnecosum</i> cf. <i>brachypterum</i> (Grav.)	13	5	32	18	20	16	16
<i>Acidota crenata</i> (F.)				1	1	1	1
<i>Anthophagus alpinus</i> (Payk.)	3	1	4	4	1	1	1
<i>Syntomium aeneum</i> (Müll.)	1	2	1	2	1		
<i>Oxytelus fulvipes</i> Er.	16	7	15	28	26	3	27
<i>Stenus</i> sp.						1	1
<i>Stenus</i> spp.	1	3	5	5	4		
<i>Lathrobium terminatum</i> Grav.		1	1	3	1	2	9
<i>Lathrobium</i> (s.l.) sp.	1	2		1	1	2	2
<i>Cryptobium fracticorne</i> (Payk.)		1					
<i>Othius</i> sp.				1	2		
<i>Erichsonius cinerescens</i> (Grav.)						1	1
<i>Philonthus nigrata</i> (Grav.)					1		
<i>Philonthus</i> sp.						1	
<i>Quedius umbrinus</i> Er.		2		1	1		
<i>Quedius</i> sp.		1	2	2	3	3	3
<i>Quedius</i> spp.	1		1		2		1
<i>Quedius</i> / <i>Philonthus</i> sp.	1		1			1	
<i>Mycetoporus</i> sp.				2		1	1
<i>Mycetoporus</i> spp.	2	3	4		2		
<i>Sepedophilus</i> sp.	2	3	3				1
<i>Tachinus rufipes</i> (L.)	2						
<i>Tachinus marginellus</i> (F.)	6	4	3	2		1	1

<i>Gymnusa brevicollis</i> (Payk.)						1	1
Aleocharinae indet.	5	6	4	5	5	2	2
Pselaphidae							
<i>Bryaxis puncticollis</i> (Denny)		1	1			1	1
Lymexylonidae							
<i>Hylecoetus dermestoides</i> (L.)					1		
Elateridae							
<i>Ctenicera pectinicornis</i> (L.)							1
<i>Selatosomus</i> sp.		1		1			
Nitidulidae							
<i>Epuraea</i> sp.			1	1	2		
Rhizophagidae							
<i>Rhizophagus parvulus</i> (Payk.)					1		
Lathridiidae							
<i>Dienerella</i> sp.			2	1		2	2
<i>Corticaria</i> sp.	1				1		
Colydiidae							
<i>Cerylon ferrugineum</i> Steph.		1	2	1	1	1	
Anobiidae							
<i>Anobium/Hadrobregmus</i> sp.							1
Serropalpidae							
<i>Orchesia</i> sp.	1						
Chrysomelidae							
<i>Longitarsus</i> sp.	4	3	5	4	5	2	9
Scolytidae							
<i>Scolytus</i> cf. <i>ratzeburgi</i> Jans.			1	1	1		
<i>Hylastes</i> sp.	1		1				
<i>Tomicus piniperda</i> (L.)	3	1		1	2		
<i>Pityophthorus</i> sp.					1		
Curculionidae							
<i>Apion</i> sp.	1		2	3	2	4	5
<i>Otiorhynchus nodosus</i> (Müll.)				1			

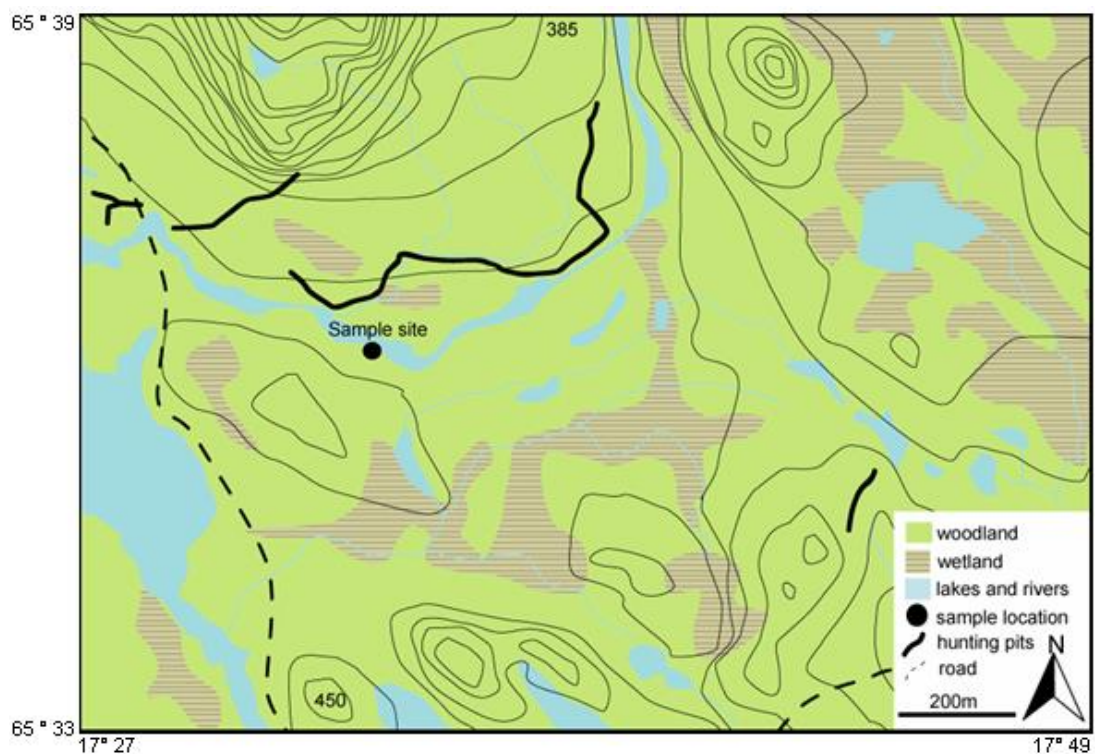
<i>Phyllobius maculicornis</i> Germ.	1						
<i>Dorytomus</i> sp.		1	1				
<i>Ellescus bipunctatus</i> (L.)					2	1	2
<i>Magdalis carbonaria</i> (L.)							1
<i>Anoplus plantaris</i> (Naezen)	1	1	2	1			1

**Table 8.9** Norrheden Faunal list.

## 9 Sorsele

### 9.1 Site description

The sampling site is located 7km north of the modern town of Sorsele, on the south bank of the Lais River (N 65° 36.568, E 17° 33.755). Around 5km to the northwest the Lais River meets with the Vindelälven, a major river running 445km from the Norwegian mountains and draining into the Umeälven 30km from the coast (Ekman and Iregren 1983; Johansson 2005). The forests of the Vindelälven valley, situated within the boreal forest zone, are dominated by Norway spruce and Scots pine, while deciduous trees constitute only a small part of the woodland (Sjörs 1965; Kempe and von Segebaden 1990, 57-58). Low hills punctuate the landscape, reaching heights of around 500 m, gradually rising into the mountain foothills of the Scandes in the west. Extensive peatlands form in the depressions, and large lakes, following the west-east gradient of the landscape, are numerous.



**Figure 9.1** Map of the area around Sorsele. Thin black lines are contour lines showing the topography of the landscape, and numbers are m asl.



**Figure 9.2** The location of the sample site in the natural landscape, with the investigated pit dwellings marked (Larsson *et al.* 2009).

Samples were taken from a small birch fen within an eroding palaeochannel, around 50 m from the river shore, at an elevation of 353 m asl (Figure 9.1 and Figure 9.2). The site lies on glaciofluvial sediments, with well-drained, sandy soil (Larsson *et al.* 2009). The closest archaeological dwelling, part of the nearby settlement site, occurs approximately 20 m west of the sampling location (Larsson *et al.* 2009). The land gradually rises with distance from the riverbank, from 352 m at the shore edge, flattening out into a mire-dominated plateau at 361m asl.

A light *Pinus sylvestris* and *Picea abies* dominated forest surrounds the fen. *Vaccinium vitis-idaea*, *Empetrum nigrum* and *Calluna vulgaris* dominate the woodland floor, with mosses and lichens comprising the dry, sandy heath vegetation. Much of the coniferous forest is now managed and more extensive areas of open land have been created further from the riverbank. To the south and southwest of the sample site open mires are extensive. On the north side of the river the coniferous forest is denser, and deciduous trees, mostly birch, form a thin belt between the river

and the coniferous forest (Larsson *et al.* 2009). Several small islets are found in the river to the east of the site.

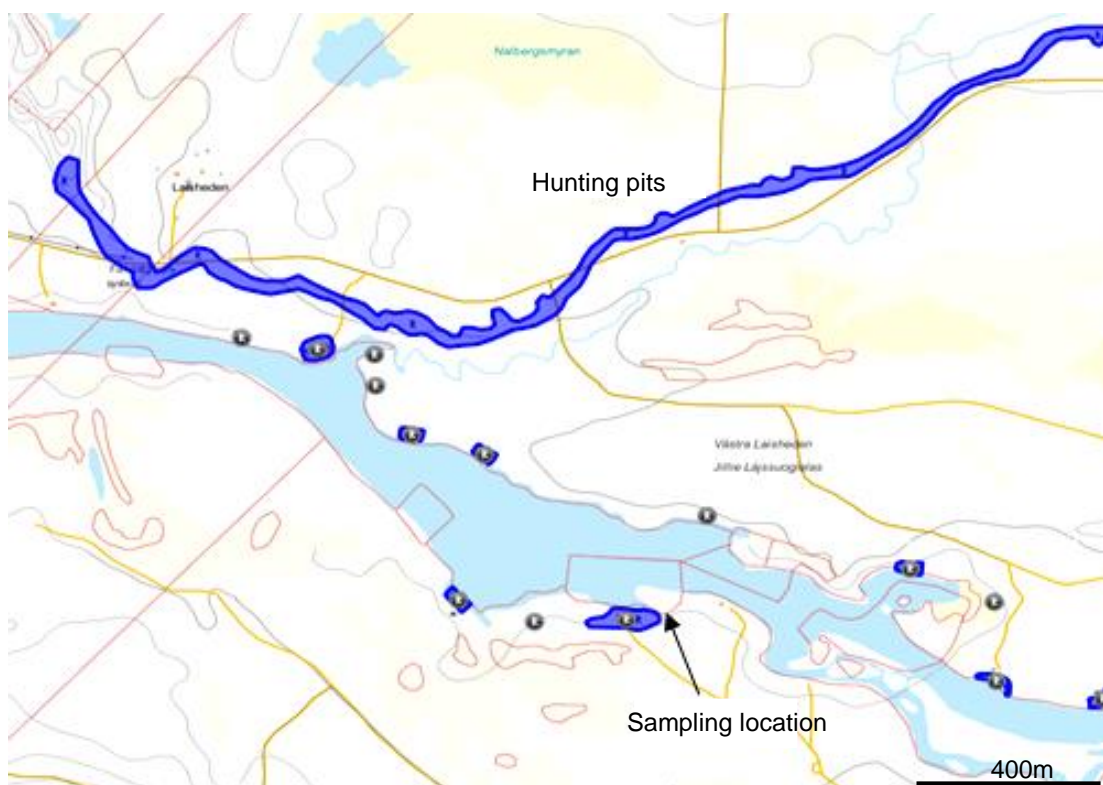
Average January temperatures in the area are -14°C with summer average temperatures of 14°C (Alexandersson and Eggertsson Karlström 2001). The first autumn frosts start in September, the last frost occurs in early June and a vegetation period of 130-140 days is usual in this area (Alexandersson and Eggertsson Karlström 2001).

## **9.2 Cultural history**

A cluster of archaeological features consisting of shallow depressions and associated embanked hollows are all that remains of the nearby settlement. Such “pit dwellings” have previously been dated to the period c. 4500-2000 BC (cf. Lundberg 1997). Worked stone, mostly of quartzite, and slate tools, burnt bone fragments and cracked stones were found in all but one of the five excavated dwellings from the settlement site (Figure 9.2), a selection of finds that has also been found at several other prehistoric sites within the forest zone of the inland north (cf. Forsberg 1985). Recent investigation of one of the Sorsele structures produced an arrowhead of Sunderøy type, suggesting use in the Late Neolithic/Early Bronze Age. Radiocarbon dates from charcoal within the structures, one of 4720-4500 BC, the other 2050-1890 BC, suggest site use in the Mesolithic and Late Neolithic (Larsson *et al.* 2009), although the problem of long residence time of charcoal in the soil profile may cast some doubt on the earlier date, if not both.

To the north, on the opposite side of the river, is an impressive chain of hunting pits, the longest in Norrland, and it has been speculated that this pit system may be related to the occupation site at Sorsele (Larsson *et al.* 2009). Dating results of charcoal from hunting pits in the western part of the 2km long chain fall within the Early Iron Age (Melander 1980). The chain runs across land varying in topography, dominated by forest and mire. In some parts it is separated from the northern river bank by a small stream with heavily forested shores.

The shores of the Lais River are littered with finds of burnt bones, scrapers and cracked stones, indicating recurrent human exploitation of the area (Larsson *et al.* 2009). On the north banks of the river are the remains of several prehistoric settlements, occurring in the area between the river and the hunting pit chain (Figure 9.3). Similar clusters of prehistoric remains are found both to the north and west where further hunting pit chains have been identified. On the south side of the river the recognised settlement remains are few and far between, however 50 m to the west of the investigated settlement another possible prehistoric dwelling has been identified (Figure 9.3 **Error! Not a valid bookmark self-reference.**).



**Figure 9.3** The location of the Sorsele samples in the cultural landscape. Grey dots are recorded archaeological features and blue areas signify a cluster of connected features (Riksantikvarieämbetet 2012).



### **9.3 Sampling**

The uppermost 10cm of modern surface material was removed, after which samples were obtained in 5cm slices yielding three litres of sediments in each, in a succession ranging from 0-65cm. The surface sample was analysed and will be discussed with regards to its representation of the modern environment at the sampling site.

Charcoal was found in Sample 12 (55-60cm), with one large piece approximately 1cm in length and several small fragments. Charcoal was also recovered from the basal sample (Sample 13).

### **9.4 Preservation**

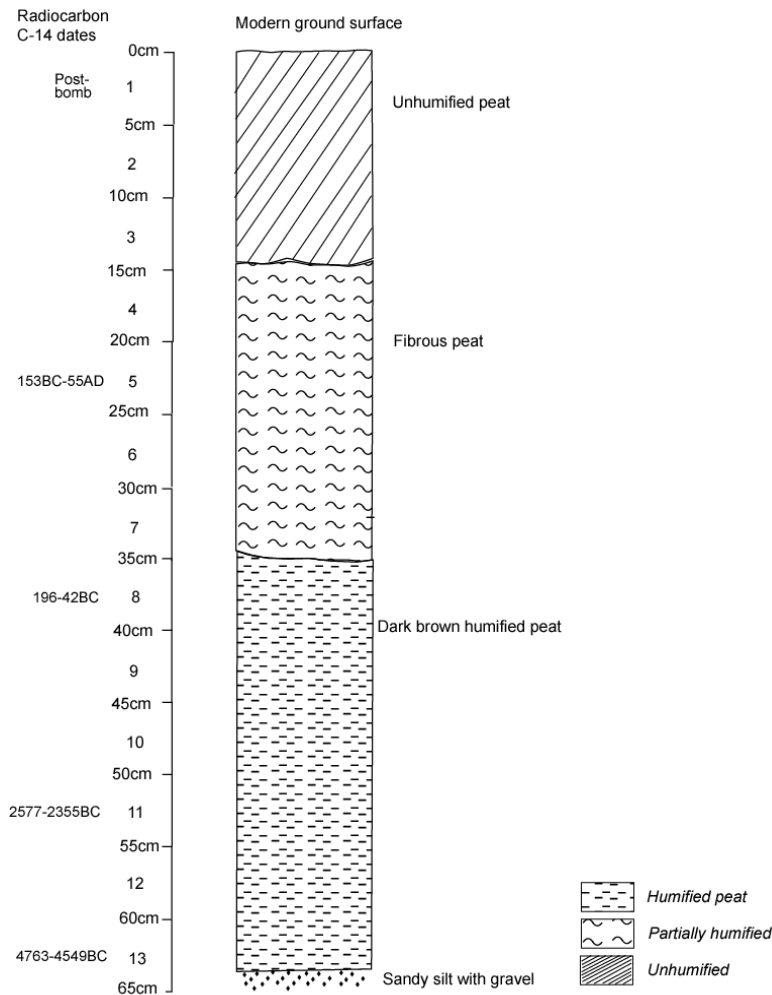
Preservation was very poor in the lowest sample, where the sediments were mostly sand and gravel. The recovered specimens from the succeeding sample were better preserved, but several of the remains were none the less corroded, pale and fragile. In Sample 9 (40-45cm) the quality of preservation was mixed. Preservation in the rest of the sequence was good.

### **9.5 Dating**

Four radiocarbon dates from seeds and pine cones have provided secure dates for this sequence. These materials were chosen due to their short life span and relative safeguarding against contamination compared with other organic remains (Bowman 1990; Kilian *et al.* 1995, Nilsson *et al.* 2001), thereby minimising error. In addition, a date from charcoal from the lowest sample of the profile provides a basal date from the Late Mesolithic (4763-4549BC).

Depth	Material dated	Uncalibrated date (BP)	Calibrated age with 95.4% probability (2σ)	Lab Codes
0-5cm	Seeds: <i>Carex nigra</i> (L.)	1.1901 ± 0.0037 <i>fraction modern</i>	Post-bomb	GU-23317
20-25cm	<i>Pinus</i> cone	2025 ± 30	153BC-55AD	GU-23318
35-40cm	<i>Pinus</i> cone	2090 ± 30	196-42BC	GU-23319
50-55cm	Macrospores: <i>Selaginella</i>	3975 ± 30	2577-2355BC	GU-23320
60-65cm	Charcoal	5806 ± 32	4763-4549BC	Ua-40616

**Table 9.1** Radiocarbon dating results from Sorsele.



**Figure 9.4** The stratigraphic profile from Sorsele showing the calibrated radiocarbon dates.

## 9.6 Results

In the basal sample only *Eucnecosum* cf. *brachypterum* and an unidentifiable Carabid head were found, the depositional environment proving unfavourable for preservation. *E. brachypterum* is found in every sample collected from this sequence; it is a species inhabiting a diverse range of habitats. Brundin's (1934) record of *E. brachypterum* in northern Sweden would suggest a main affiliation with grass and herb rich meadows and heaths and, where found in wooded localities, the tree cover is of light deciduous trees. The species is often found in association with water, residing in the vegetation littering the banks of streams (Brundin 1934; Campbell 1984).

The faunal assemblage from Sample 12 also appears to have been affected by adverse preservation, although to a lesser extent, allowing the recovery and identification of several species. *Olophrum consimile* and *Olophrum rotundicolle* have most frequently been recorded from the vicinity of water, whether rivers or bog pools (Campbell 1983; Koch 1989a; Hyman 1994; Böcher 1995). They are primarily found in damp bogs and meadows in such areas, or amongst the leaf-strewn, mossy ground layer beneath alder and willow (Strand 1946; Böcher 1995).

Members of the genus *Stenus* often inhabit the grasses, mosses and decaying vegetation in wetland environments, sometimes in the vicinity of woodland and less frequently in dry meadows (Larsson and Gíjja 1959; Lindroth *et al.* 1973; Koch 1989a). Also exploiting the damp ground litter is the riparian *Lathrobium terminatum* Grav. (Brundin 1934; Lott and Anderson 2011).

The fauna also includes *Dyschirius globosus* (Hbst.), a species found in all types of wet, vegetated ground including bogs, fens, meadows, heaths and river shores, and which is common throughout Scandinavia (Lindroth 1985; Koch 1989a; Fedorenko 1997), where it is usually indicative of open conditions (Lindroth 1974; Duff 1993). In the northern part of its range *Patrobus assimilis* Chaud. has been found on dry, open ground, usually in heathland vegetation, as well as in forested localities

(Lindroth 1985). Heaths and bogs are the primary habitat of *Pterostichus diligens* (Sturm), often on river shores (Larsson and Gíjja 1959; Lindroth 1986).

The aquatic component of the Sample 12 assemblage includes *Hydroporus* cf. *melanarius* Sturm, which is found in temporary, peaty bog pools, often in *Sphagnum* in the shade of forests (Koch 1989a; Nilsson and Holmen 1995; Merritt 2006). *Agabus* sp. are also usually found in pools (Nilsson and Holmen 1995), while *Hygrotus versicolor* (Sch.) and *Elmis aenea* (Müller) are more commonly found in running water in streams and rivers (Duff 1993). The woodland fauna includes *Orchesia micans* (Panz.), a false darkling beetle associated with fungi, mainly on deciduous trees, which are often rotting (Koch 1989ab).

Samples 10 and 11 indicate a diversification of the woodland fauna. The light, broadleaved forest played host to *Rhamphus pulicarius* (Hbst.) feeding on *Salix* and *Betula* in exposed areas of meadows and in clearings in woodlands and river margins (Koch 1989a). The polyphagous tree and herb feeder *Phyllobius* is also present. Currently the only species of this genus living in Västerbotten is *P. maculicornis* which is found upon young birch trees and shrubs, and quite often from sparsely wooded grassy areas (Austarå *et al.* 1984; Palm 1996; Morris 1997). The needles of *Pinus sylvestris* trees play an important part in the life cycle of the weevil *Brachonyx pineti* (Payk.) which overwinters, lays eggs and feeds on this host tree (Bakke 1958; Bullock 1993). The larvae of *Anthonomus phyllocola* (Hbst.) mature in the flowers of pine trees (Morris 1977). Sample 4 also contained *Cis* sp. Most species of this genus are attracted to the fungoid wood of deciduous trees, although others are known from coniferous woodlands (Koch 1989ab). *Rhynchaenus rusci* (Hbst.) is a deciduous woodland beetle, the larvae developing in *Betula* leaves (Koponen and Nuorteva 1973) in woodland margins and clearings (Koch 1992). *Tomicus minor* (Hartig) is recorded from coniferous woodland where it invades stressed or standing dead trees (Lekander *et al.* 1977), occasionally resulting in the death of the host tree (Solheim *et al.* 2001). *T. minor* usually occurs as a secondary coloniser following the attack of weakened trees by *T. piniperda* (Långström and Hellqvist 1993).

Alongside the tree fauna in Sample 10 is a single occurrence of *Rhagonycha testacea/limbata* (L.)/(Thoms.), a species found in open, exposed places in the vicinity of woodland, where it is a predator found on meadow flowers, heathland shrubs and small deciduous trees (Koponen and Nuorteva 1973; Koch 1989ab). Also new in this assemblage is *Agonum fuliginosum* which is found mostly in bogs, although it is also known from damp woodlands and meadows, preferring shaded habitats where it resides amongst mosses and vegetative litter (Koch 1989a). It has often been recorded from, but is not restricted to, habitats in the vicinity of water (Koch 1989a; Duff 1993). *Cyphon* sp. are also present, many species of which require shallow water and are found in *Sphagnum* bogs and waterside vegetation, sometimes in the vicinity of carr woodland (Harde 1984; Koch 1989ab). The damp and mouldy vegetation in bogs and by rivers is also home to the minute beetle *Clambus armadillo* (Deg.)(Koch 1989ab; Johnson 1992), while *Mycetoporus* sp. inhabit a range of habitats from dry sandy heaths to damp river meadows, bogs and woodland (Koch 1989a; Hyman 1994).

In Sample 9 the previous woodland species disappear, replaced by *Epuraea* sp., and by several species currently found in the area, most of which are found in woodland habitats, under bark, in tree fungi and in sap. Some have been recorded from felled tree stumps and decaying wood of cut or burned trunks (Koch 1989ab; Palm 1951; Palm 1959). Numbers of *E. brachypterum* peak, alongside *Quedius* sp., the latter being common predators amongst the ground litter of wetlands and woodlands (Koch 1989a). *Philonthus nigrata* (Grav.) is found in bogs and marshes dominated by *Sphagnum* and *Calluna* heath (Marsh 1991; Lott 2003), and it has also been recorded from shoreline drift in the Baltic (Backlund 1945). Preservation of some specimens was excellent; however a few remains were very translucent and fragmented.

Sample 8 sees the reappearance of woodland fauna and *Rhyncolus ater* (L.) enters the sequence, exploiting the rotting hardwood of pine trees, whether standing, cut or fallen (Koponen and Nuorteva 1973). It is also known from deciduous woodland, again preferring old and decaying substrates in which it feeds and reproduces (Koch 1992). Deciduous woodland dwellers of the genus *Dorytomus* occur simultaneously;

many species are known from *Populus* and *Salix* in wetlands and open wood pasture landscapes (Hyman 1992). *Ctenicera pectinicornis* is a meadowland species, found in rich grasslands in both dry, sandy soils and also from damp areas (Koch 1989ab; Duff 1993). Woodland clearings and margins are common habitats of this species (Koch 1989ab; Laibner 2000). At this point in the sequence *Miscodera arctica* (Payk.) also appears, a Carabid most commonly found in rather dry and sandy localities, notably heathlands of *Calluna* and *Empetrum* and sparse coniferous woodlands (Böcher 1995; Lindroth 1985). *Tomicus piniperda* is a scolytid which is found primarily in association with pine trees, and occasionally spruce, both in healthy and also in damaged or dead trees, and logs (Lekander *et al.* 1977). It is first found in Sample 8, and infrequently in the following samples.

The dry heathland carabids *M. arctica* and *P. assimilis* were identified alongside damp ground species of *Olophrum* spp. in Sample 7, while aquatic species are present only in small numbers. A single elytron of *Atomaria* sp. could not be identified to species level; this large genus is adapted to various types of habitat including decaying, mouldy vegetation in grasslands, wetlands and river edges, rotting tree bark and herbivore dung (Koch 1989ab; Johnson 1993; Hyman 1994).

*Magdalis carbonaria* (L.) enters the sequence in Sample 6, dead twigs and branches of birch trees providing nourishment for the larvae of this species (Hyman 1992), often at woodland margins (Koch 1992; Pavett and Levey 2001). It occurs alongside the tree-associated species *Dorytomus* sp. and *T. minor*. *Stenus* and *Lathrobium* spp. return, as does *Agabus*, and *Otiorhynchus nodosus* (Müll.) appears for the first time in the sequence. This flightless weevil is primarily associated with open meadow and heathland habitats where it forages amongst herbs and is also known from light woodland and drier areas in bogs (Böcher 1988; Koch 1989ab).

From Sample 5 *Phratora vulgatissima* (L.) appears, a chrysomelid associated primarily with willow and poplar in river-side meadows and damp woodlands (Bullock 1993; Koch 1992). *Crepidodera fulvicornis* (F.) is similarly known from *Salix* and *Populus* by river banks and in flood debris (Bullock 1993; Koch 1992).

Specimens of *Calathus melanocephalus* (L.) were recovered from Samples 4 and 5; this is a species of dry and open grassland or heaths (Lindroth 1974). *Ampedus balteatus* (L.) was also recovered, an elaterid found in the rotten stumps and inner bark of coniferous and deciduous trees often in boggy ground (Koponen and Nuorteva 1973; Koch 1989ab). Sample 4 produced the small pselaphids *Bryaxis bulbifer* and *Pselaphus heisei*, both common in marshes where *Sphagnum* and grasses provide shelter (Pearce 1957; Duff 1993). *Atomaria* sp. occur in the vegetative litter or rotting substances within the bog environment or the wider woodland (Palm 1959; Koch 1989ab).

Sample 3 yielded the tree-dependent species *P. vulgatissima* and *Anthonomus phyllocola*, and the highest numbers of *O. nodosus* found in the sequence. The uppermost 10cm contain only a small number of specimens, with *P. vulgatissima* the only tree-dependent species. Staphylinids *E. brachypterum*, *Olophrum* spp, *Stenus* sp. and *Lathrobium* sp. are present.

## **9.7 Discussion**

From the palaeoecological sequence, a basal date of 4763-4549 BC may equate the lowest samples with the suggested date of initial occupation at the site in the Late Mesolithic/Early Neolithic. A radiocarbon date from a charcoal layer in the embankment of one of the dwellings returned a date of 4720-4500 BC (Larsson *et al.* 2009). This should be regarded as the earliest possible date of this dwelling. Whether the occurrence of macroscopic charcoal, both from the palaeoecological succession and from the settlement site around the Late Mesolithic/Early Neolithic transition, is from natural or anthropogenic fire cannot be confidently assessed on the current data. Unfortunately the poor preservation conditions of Sample 13 mean that the associated fauna could not be studied.

Although preservation of the Sample 12 fauna was quite poor, several taxa were able to be identified, including the aquatic beetles *Hydroporus* cf. *melanarius* and *Agabus* sp., often found in bog pools, and *H. versicolor* (Sch.) and *E. aenea* (Müller) which inhabit running water (Duff 1993). Many species found in damp bogs, on the banks

of streams and rivers were found, including *O. consimile* and *O. rotundicollis*, *L. terminatum*, *D. globosus* and *P. diligens* (Backlund 1945; Campbell 1983; Lindroth 1986; Hyman 1994; Fedorenko 1997). This faunal assemblage indicates that a stream or river was flowing nearby, and that the banks were littered with plant debris. This may indicate that the palaeochannel identified at the site was active at this time.

An increasing number of staphylinids are found in the following samples, accompanying an expansion in the tree-dependent fauna. *Rhagonycha testacea/limbata* frequented the exposed ground vegetation by the river margins (Koponen and Nuorteva 1973; Koch 1989ab). Species found in damp bogs and near to freshwater habitats include *A. fuliginosum* and *C. armadillo* (Lindroth 1945; Johnson 1992). The soil profile shows that peat began to form at this time. The palaeoecological evidence indicates that the channel may have begun to infill, with the build up of vegetation and the formation of peatland. This change may also have been driven by changes in landscape dynamics related to isostatic uplift, as water ways and lake outlets were altered with the changing topography of the land (Påsse 1998; Bergman *et al.* 2003; Hörnberg *et al.* 2005; Eronen 2005).

Species which feed on deciduous trees include *R. pulicarius* and *R. rusci*, the latter particularly indicative of *Betula* (Koponen and Nuorteva 1973). Koch (1990) has recorded it primarily from open, light areas by rivers, bogs and in woodland margins. Coniferous woodland is also represented, with *A. phyllocola* and *B. pineti*, both of which depend upon pine trees in various stages of their life cycles (Bakke 1958; Morris 1977; Bullock 1993). *T. minor* is most commonly found in *Pinus sylvestris*, although it appears to exploit various *Pinus* and *Picea* species (Lekander *et al.* 1977; Bullock 1993). It exploits mature trees and standing snags as well as damaged trees (Lekander *et al.* 1977; Winter and Evans 1990) and its presence may suggest that mature or distressed pine trees were close by. *Cis* sp. is affiliated with fungus infested wood (Koch 1989ab). The fauna indicate that trees began to encroach onto the developing bog surface. The initial colonisers were probably deciduous trees tolerant of wet conditions were the initial colonisers, with coniferous trees growing



in slightly drier areas. This evidence can be dated from c.2355 BC, during the Neolithic and into the Early Bronze Age.

A predominantly wet meadow/wetland fauna was recovered from Sample 9. *E. brachypterum*, which reaches its peak in this sample, is indicative of fairly open conditions, and *Hydroporus* spp. inhabited the water pools on the bog surface. *Epuraea* sp., of which two individuals were recovered, may be associated with the woodland habitat (Koch 1989ab; Palm 1951; Palm 1959). The tree fauna is limited in comparison with the evidence of a forested landscape interpreted from the preceding and following samples. Some specimens in this sample were very well preserved, while others were more poorly preserved, characterised by pale, fragile specimens. This admixture may suggest that the assemblage has been compromised by post-depositional factors, such as periodic drying-out or exposure, or could indicate variable origins of the assemblage, with some individuals perhaps being washed in (Sadler 1991, 8; Kenward and Large 1998).

The species that were identified from Sample 9 are clearly indicative of open, wet conditions. This can be dated to the Bronze Age, around the Mid-1<sup>st</sup> millennium BC. Archaeological finds from the settlement that are broadly contemporary with this episode include a Sunderøy-type arrow head, dated to the Late Neolithic/Early Bronze Age and could suggest occupation during this period (Larsson *et al.* 2009). Forsberg's (1985) model of prehistoric settlement along the Luleälven suggests that by this time a bipolar system of settlement between the forests and mountain foothills had become well established, and involved the use of larger residential camps in the forest area. Changes in hydrology around a site, caused by changes to the vegetation cover and/or the impediment of drainage, can occur as a result of human activity (Charman 2002; Rydin and Jeglum 2006). Removal of the mor humus layer by Sámi groups in the setting up of the nearby settlement, and/or the grazing of reindeer, could potentially be activities that altered site hydrology, and this cannot be ruled out as a possible influence upon the local environment at this time. However, during this period, tree-ring evidence from northern Sweden has shown that a severe climatic deterioration took place, and extremely cold conditions occurred in 330 BC (Grudd

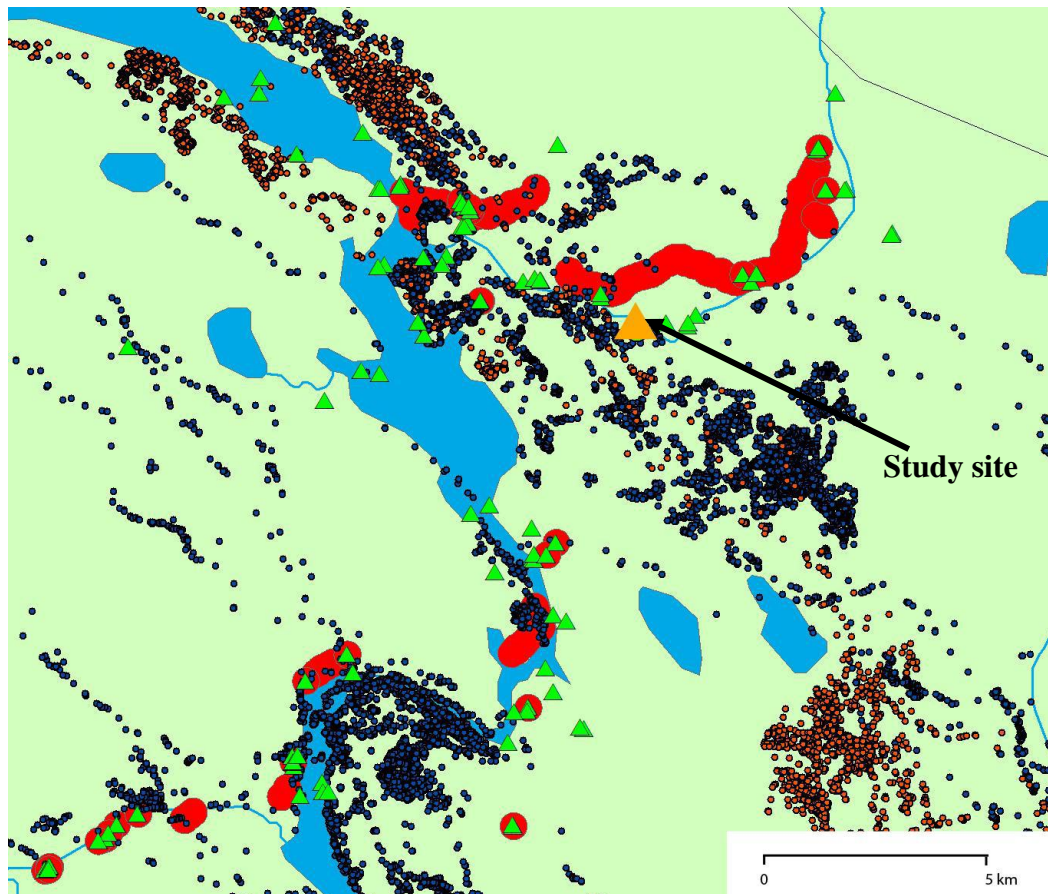
*et al.* 2002). The environmental change seen at the site during this time could therefore have been influenced by climate, encouraging the expansion of wet bog and limiting tree-growth. It is difficult to ascertain whether this environmental change was driven primarily by natural or anthropogenic influences.

The reappearance of tree-dependent fauna in Sample 8 suggests the recovery of the tree canopy at this time, dated to 196-42 BC. *Dorytomus* sp. may have inhabited the deciduous trees growing in the woodland. The occurrence of insect species exploiting coniferous trees, alongside a prevalence of pine cones recovered from the sample, demonstrates that the coniferous forest began to recover during this phase. The same sample yielded *C. pectinicornis* and *M. arctica*, species of quite dry, sandy open grass and heathlands (Lindroth 1985; Duff 1993; Böcher 1995). Both are able to fly and could be indications of the development of such habitats around the nearby settlement. The hygrophilous ground beetles are reduced in number and diversity in this sample, although the aquatic species remain. The insect fauna suggest that woodland prevailed at the site, dominated by pine. The ground layer was perhaps drier and sandier than previously seen.

In Sample 7, tree-dependent species are entirely absent, contrasting with the samples preceding and following it. The wetland staphylinid population is similarly reduced. The Carabid *M. arctica* occurs, which has been recorded in Fennoscandia in *Empetrum* and *Calluna* heath vegetation on sandy soils, generally in open localities or in light pine woodlands (Lindroth 1985). *P. assimilis* has been recorded from similar habitats in northern Scandinavia, although it also can be found in damp areas (Lindroth 1985). Low numbers of species/individuals were found in this sample, although preservation was good. The dating evidence suggests that the rate of accumulation was slow during this period. The evidence for a more open and perhaps drier landscape occurs in the centuries around BC/AD, the Early Iron Age.

The environmental change at this time is more substantial than previously seen. There is no evidence that the settlement site was being utilised at this period, however the site was well placed for exploiting migrating elk. To the south is the winter pasture, to the north, in the mountains, are the summer and autumn grounds.

The hunting traps are well located to intercept the migrating elk (Figure 9.5). The finding of large bone, possibly an elk jaw and the elevated phosphate and pH values from the dwellings, have led Larsson and others (2009) to suggest that bone deposition here may initially have been significant, indicating the processing of elk carcasses on site. Dating evidence from the trapping pits to the north suggests that these were in use during the Early Iron Age (Melander 1980), indicating human activity/occupation in the area during this period. Similar settlement remains, of a pit with surrounding mound and associated fire cracked stone, dated to the period 4500-2500 BC, have been found in association with pit fall traps and elk bone remains in inland Norrland, possibly used on a year-round basis (Lundberg 1997). The site may have been functional as a residential base. The insect faunal evidence is not sufficiently strong to conclude that the environmental change was purely driven by human activity at the site, although it seems likely to have been an influencing factor.



**Figure 9.5** Map of the study site, showing modern elk migration and the position of ancient pitfall traps. The dots reflect the positions for elk with GPS collars in the area around Sorsele. *Blue dots:* cow elk *Orange dots:* bull elk *Green triangles:* settlements *Red:* Pitfall traps (map from Larsson *et al.* 2009).

After this the site once again became wooded, although not to the extent previously seen. The inclusion of deciduous tree species of *Dorytomus* sp. and *M. carbonaria* in Sample 6, the latter usually found in areas of sparse tree cover, such as lightly wooded heaths, bogs and forest edges (Koch 1992) and the presence of coniferous dwelling scolytid *T. piniperda* (Lekander *et al.* 1977) indicates mature or disturbed woodland in the immediate surroundings. Damp-loving beetles increased in number and aquatic species of *Hydroporus* and *Agabus* were present. The environment was damp and lightly wooded.

*Calathus melanocephalus*, which appears in Sample 5, suggests open, dry grassy areas. From this point the fauna indicate that deciduous trees and shrubs replaced the coniferous forest. Six pine cones and a large piece of wood were also found in Sample 5. Despite the macrofossil evidence suggesting forest in the immediate locality, the indication of woodland is not strong in the insect fossil data, suggesting a light covering of deciduous trees, as no coniferous species were recovered.

Samples 3 and 4 reflect a semi-open environment with damp grasses and mosses and drier areas within a bog or meadow. *A. balteatus* indicates dead or rotting wood (Koponen and Nuorteva 1973), while the remaining tree-dependent species are found in open areas in meadows and river margins. The fall in the number of recovered species in Sample 2, which is characterised by hygrophilous staphylinids, aquatic *Hydroporus* species and a single occurrence of *O. nodosus*, reflects a damp and relatively open environment. It would appear that during this time the wetland hosted a light covering of trees and shrubs within sparse woodland.

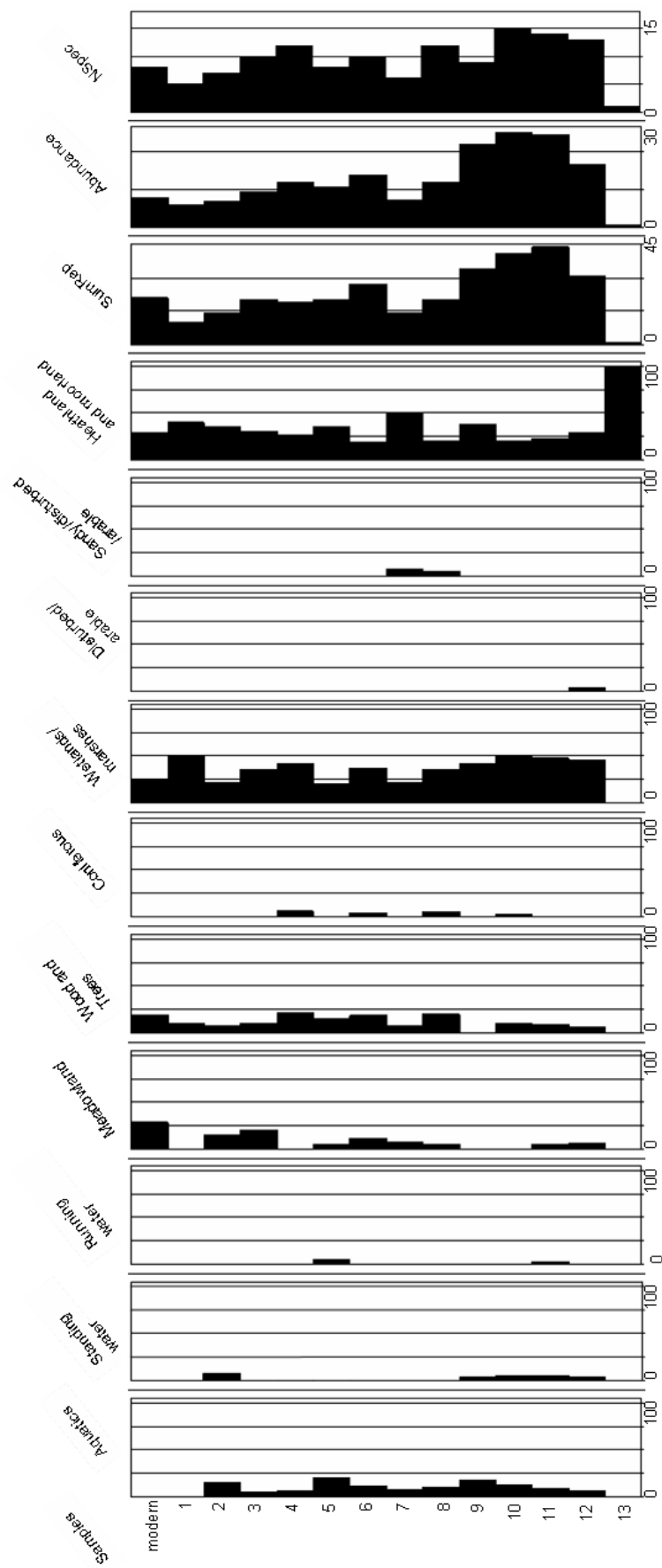
Sample 1 had a single occurrence of *P. vulgatissima*, which is likely to have resided in *Poplar* and *Salix* in the damp fen/river margins, while the staphylinids roamed the damp ground layer. The aquatic fauna were absent from this fauna, and alongside the decline in hygrophilous staphylinids, suggest that a drier habitat prevailed. This sample dates to the modern period, and the assemblage indicates that prior to the expansion of the birch fen now characterising the site, the local environment was

dominated by a damp bog with little tree cover. Fluctuating levels of wetness are indicated over this period.

It is evident that coniferous-dwelling beetles were gradually replaced by deciduous-associated species, and areas of open, dry and sandy ground became small but persistent elements in the landscape. This shift could be connected to earlier utilisation of the site, altering the environment and its subsequent development. This recolonisation of abandoned areas by *Betula* is a pattern seen at other sites in northern Scandinavia (Hicks 1993; Carpelan and Hicks 1995; Josefsson *et al.* 2010b). It is possible that human groups were exploiting the area, perhaps on a periodic or infrequent basis, maintaining the mosaic structure indicated by the insect remains, although this can not be concluded with certainty and the vegetation structure may have been maintained by natural processes.

The modern ground layer sample includes *E. brachypterum*, *O. rotundiolle*, *L. terminatum* and *Lathrobium* sp., inhabitants of the damp vegetation in bogs and heaths. The elaterid species include *Eanus* sp., the only species of this genus found in Sweden today is *E. costalis*, known from coniferous forests in Scandinavia (Väisänen *et al.* 1993). *Athous* spp. generally inhabit grassy or heathy openings in areas of light forest (Duff 1993; Koch 1989ab). *P. vulgatissima*, found throughout the upper 30cm of the sequence, is present among *Salix* in fen woodland. *A. fuliginosum*, an inhabitant of fens and woodlands, is seen once again. The eurytopic *O. nodosus* is prevalent, indicating open conditions, while *Patrobus assimilis* is similarly found in open grass or heath dominated areas near woodlands. The woodland dwelling *A. balteatus* is perhaps indicative of rotting wood within the forest (Koponen and Nuorteva 1973).

This assemblage indicates a damp bog/fen environment with surrounding forest of coniferous trees, with deciduous trees and shrubs at the margins or on the fen surface itself. Dry areas of heath or open grassy areas are also suggested. This fits well the modern vegetation of the site, of a small birch-dominated fen, surrounded by a pine and spruce forest with dry heath vegetation.



**Figure 9.6** BugsEcofig. Calculations based on abundance data. Diagram showing the abundances of species in certain habitat groups at Sorsele.

Sample 1: 0-5cm (Post-bomb)

Sample 2: 5-10cm

Sample 3: 10-15cm;

Sample 4: 15-20cm

Sample 5: 20-25cm (153BC-55AD)

Sample 6: 25-30cm

Sample 7: 30-35

Sample 8: 35-40cm (196-42BC)

Sample 9: 40-45cm

Sample 10: 45-50cm

Sample 11: 50-55cm (2577-2355BC)

Sample 12: 55-60cm

Sample 13: 60-65cm (4763-4549BC)

Sample	Mod	1	2	3	4	5	6	7	8	9	10	11	12	13
Sample depth (cm)	5-0	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
Radiocarbon age		Post-bomb				153BC-55AD			196-42BC			2577-2355BC		4763-4549BC
Faunal list														
Carabidae														
Carabidae indet.								1						1
<i>Dyschirius globosus</i> (Hbst.)													1	
<i>Miscodera arctica</i> (Payk.)									1	1				
<i>Bembidion</i> sp.	1												1	
<i>Patrobus assimilis</i> Chaud.	1		1	1			1	2	1				2	1
<i>Pterostichus diligens</i> (Sturm)						1					1	1	1	1
<i>Calathus melanocephalus</i> (L.)						1	1							
<i>Agonum fuliginosum</i> (Panz.)	1											1		
Dytiscidae														
<i>Hygrotus</i> sp.														3
<i>Hydroporus tristis</i> (Payk.)			1								1	2	2	1
<i>Hydroporus</i> cf. <i>melanarius</i> Sturm			1	1	1	3	3	1	2	5	3	1	1	
<i>Hydroporus</i> sp.				1	2	1	1	1	1		2			
<i>Agabus</i> sp.						1	1						2	1
Clambidae														
<i>Clambus armadillo</i> (Deg.)											1			
Staphylinidae														
Staphylinidae indet.													1	
<i>Olophrum consimile</i>			1		1						3		1	1

(Gyll.)

*Olophrum rotundicolle*

(Sahl.)

1 2 1 1 3 2 4 1 3 5 5 4 3

*Arpedium quadrum*

(Grav.)

1 1 1 2 2 1 2 4 8 9 5

*Eucnecosum* cf.

*brachypterum* (Grav.)

1 4 4 3 4 6 4 6 3 12 8 10 7 1

*Eucnecosum* sp.

1 1 2 1 1 1 1 5 7 1

*Stenus* sp.

1 1 2 4 1 2 1

*Stenus* spp.

2 3 4 3

*Lathrobium terminatum*

Grav.

1 1 1 1 1 1 1

*Lathrobium* (s.l.) sp.

2 3 2

*Philonthus nigrata*

(Grav.)

1 1

*Quedius* sp.

1 1 1 1

*Mycetoporus* sp.

1 1 1

*Tachyporus* sp.

1

*Aleocharinae* indet.

1 1 1 4 2 1

Pselaphidae

*Bryaxis bulbifer*

(Reich.)

1

*Pselaphus heisei* Hbst.

1

Cantharidae

*Rhagonycha*

*testacea/limbata*

(L.)/(Thoms.)

1

Elateridae

*Eanus* sp.

2

*Ampedus balteatus* (L.)

1

1

*Ctenicera pectinicornis*

(L.)

1

*Athous* sp.

1



Scirtidae												
<i>Cyphon</i> sp.			1	2	1	1		1	2	1		
Dryopidae												
<i>Elmis aenea</i> (P. Müller)					1						1	
Nitidulidae												
<i>Epuraea</i> sp.									2		1	
Cryptophagidae												
<i>Atomaria</i> sp.			1	1			1					
Lathridiidae												
<i>Latridiidae</i> indet.										1		
Cisidae												
<i>Cis nitidus</i> (F.)										1		
Serropalpidae												
<i>Orchesia micans</i> (Panz.)												1
Chysomelidae												
<i>Phratora vulgatissima</i> (L.)	1	1	1		1							
<i>Crepidodera fulvicornis</i> (F.)				1								
Scolytidae												
<i>Scolytidae</i> indet.			1							1	1	
<i>Tomicus minor</i> (Hartig)										1		
<i>Tomicus piniperda</i> (L.)				1		1		1				
Curculionidae												
Curculionidae indet.									1			
<i>Otiorhynchus nodosus</i> (Müll.)	5	1	3			1						
<i>Phyllobius</i> sp.										1		
<i>Rhyncolus ater</i> (L.)				1				1				
<i>Dorytomus taeniatus</i> (F.)					1	1		1				
<i>Anthonomus phyllocola</i>			1					1		1	1	

(Hbst.)				
<i>Brachonyx pineti</i>				
(Payk.)		1		1
<i>Magdalis carbonaria</i>				
(L.)	1			
<i>Rhynchaenus rusci</i>				
(Hbst.)			1	
<i>Rhamphus pulicarius</i>				
(Hbst.)				1

**Table 9.2** Sorsele Faunal list

## 10 Akkajärvi

### 10.1 Site description

The site of Akkajärvi (N 66° 52.93 E 21° 6.57) lies within an area of sprawling wetlands between the drainage basins of the Kalixälven and Råneälven at an elevation of 374 m asl. The surrounding landscape is punctuated with small morainic hills and ridges. The many streams and lakes of the area are traditional Sámi summer fishing waters, while the lichen-rich spruce forests have long provided winter forage for reindeer (Aronsson 1991, 94). Forest clearance has been heavy in the wider area, although old stands of *Picea*, *Pinus* and *Betula* are prevalent in the immediate surroundings of the sampling site. The forest floor is dominated by *Vaccinium myrtillus* and *V. vitis-idaea*.

Lake Akkajärvi, one of the largest lakes in the immediate area, is situated approximately 150 metres to the east of the sample site. The area from which samples were taken can be clearly identified from modern satellite maps, occurring as a large clearing in the woodland (Figure 10.2). The modern ground vegetation in the clearing consists of Cyperaceae and Poaceae, dense mosses and stands of *Vaccinium* spp., with some solitary trees of *Betula* and *Picea*. A modern reindeer pen (*renvall*) now stands within the clearing. Outside of the penned area small scattered birch trees are present in higher numbers than inside the *renvall*. A small fen is located to the south.

The site itself has been historically utilised as a camp of the Gällivare Forest Sámi and is currently used by the Ratukka group of reindeer herders (Aronsson 1991, 94). Cultural remains in the wider area include several hearths, *kåta* and *renvall*, all of which indicate a long history of Sámi use of the area. *Kåta* (or Finnish *kota*) were the main type of Sámi dwelling in the forest zone, and includes many different types of construction, although the central hearth is a common feature (Blomqvist 2007). Some huts were timbered and covered with turf, or the branches or bark of coniferous trees, while others dwellings were not as permanent in nature and were more basic structures covered in cloth (Schefferus 1674, 83; Hicks 1993). The name ‘Akkajärvi’ is thought to have originated

from the term '*Akka*' a word used in association with traditional Sámi ideology, denoting a pre-Christian sacred place (Aronsson 1991, 96). The archaeological, place-name and ethnographic evidence all suggest a long tradition of Sámi activity in the area.

The forest reindeer herding Sámi migrate between pastures throughout the year, staying within the forest zone. Traditionally, Forest Sámi reindeer herders migrated between semi-permanent settlements in the summer, usually consisting of around three to seven dwellings, and *kåta* tent dwellings were used as they moved between winter pasture grounds, always remaining in the forest zone (Aronsson 1991, 28). This differentiates them from the mountain Sámi who spend summers in the mountains, often with larger herds of reindeer (Schefferus 1674). At Akkajärvi the site has previously been known to be used in summer months for grazing, and in earlier times reindeer were driven together for milking in *renvall*. Migrations to winter pasture grounds occurred along streams, rivers and spruce forests with abundant hanging lichen, or to the coast when winters were severe (Aronsson 1991, 95-96).

As part of the modern Forest Sámi herding system, reindeer are rounded up in pens for activities such as slaughter, calving and marking (Aronsson 1991, 34). This takes part in the spring, summer and autumn. During the earlier intensive herding system, milking was the main activity taking place in the summer and autumn grounds (Aronsson 1991, 29; Ruong 1945, 138-139). Intensive herding was carried out in the local area, as recalled by a local herder from the nearby village of Ratukkavaara. Use of the site for a short time each year, perhaps for only one to two weeks, helped to avoid disease in heavily trampled, muddy ground (Ruong 1944, 94; Manker 1968; Aronsson 1991, 94). During the period of earlier intensive herding, when milking was carried out, up to 50 sites may have been used by each herder (Aronsson 1991, 95). The local Ratukka Forest Sámi recall a period of over-use leading to the spread of disease at the studied *renvall* at Akkajärvi (Aronsson 1991, 95). This led to site abandonment and movement to a new site 1km to the southwest. After some years, a new pen was rebuilt on the original site and activity resumed in the form of extensive herding (Aronsson 1991, 95).

## 10.2 Previous work in the local area

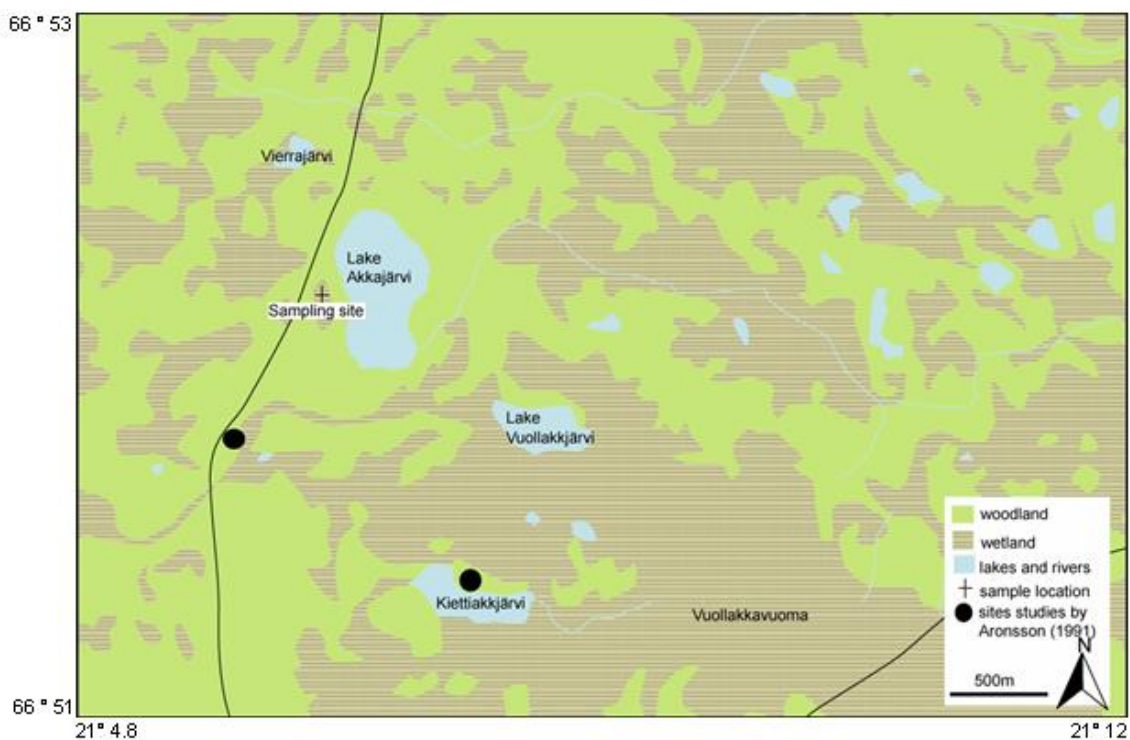
Pollen rain from five sites within the Gällivare area has been studied by Aronsson (1991). The results from the site of Akkajärvi itself and the nearby *renvall* to the southwest are discussed below.

A sample taken from peat directly beneath the vegetative layer at the study site of Akkajärvi revealed high levels of Cyperaceae and Poaceae, alongside the culture-indicator taxa *Rumex*, Chenopodiaceae, *Urtica*, Asteraceae and *Juniperus*, relating to recent reindeer herding practices at the site (Aronsson 1991).

At the site situated 1km to the southwest (Figure 10.1), established when the *renvall* at Akkajärvi was abandoned, a series of samples were taken from surface mosses at the *renvall* margin and then at distances of 10m, 25m, 75m and 150m (Aronsson 1991). This revealed that the dispersal distance of the pollen was small, with culture-indicator pollen recorded only up to 25m from the *renvall*. A pollen core was also taken from this site at a fen 25m from the *renvall*, covering approximately the last 3000 years. The uppermost levels, particularly from 10cm, display high levels of grass and herb pollen with culture indicators *Rumex*, Chenopodiaceae, *Plantago major* and *Juniperus*, reflecting the impacts of reindeer herding over approximately the last 100 years, before abandonment in recent decades. Earlier indications of occupations are found during the early 1st millennium AD, and again during the Late Iron Age/Middle Ages (c. 400-1500AD), although the signal during the earlier periods is not as distinct, including fewer culture-indicator species (Aronsson 1991, 96-97).

Sampling of the morhumus layer at an old milking ground near Lake Kiettijärvi, located approximately 1.5 km to the southeast of the sample site at Akkajärvi (Figure 10.1) recovered pollen that was badly preserved, restricting identification (Aronsson 1991). Although the site is not currently in use, and the vegetation consists of *Vaccinium* spp.

and mosses, the pollen spectra shows high levels of Poaceae levels, accompanied by disturbance indicators *Rumex* and *Epilobium*.



**Figure 10.1** Map of the landscape around the sampling area. Two *renvall* studies by Aronsson (1991) are marked.



**Figure 10.2** Akkajärvi sample location, showing the *renvall* and surrounding landscape.

### 10.3 Sampling

Samples were taken from both inside and outside of the reindeer pen, at a distance of approximately 60 metres from each other (Figure 10.3). In each case a pit was dug from which the samples were taken.

Column A (inside of the pen) reaches a depth of 40cm, where grey clay was encountered overlying the bedrock substrate. Sample 1 covers 0-15cm, with the remaining samples taken in 5cm increments. Size of samples ranged from 3-6 litres, depending on the degree of compaction and humification of the peat.

Column B (outside of the pen) reached a depth of 50cm. There was no underlying clay and the peat bottomed out on the bedrock. The two uppermost samples were taken in



2.5cm increments, each 3 litres in size. Samples 3-11 were taken in approximately 5cm increments and were 2-4 litres in size.

Pollen analysis was undertaken by Ilse Kammerling, University of Aberdeen as part of the Leverhulme project, and was similarly carried out inside and outside of the *renvall*. From inside the *renvall* the pollen core reaches a depth of 30cm, and the insects 40cm. Both reach a base of grey silty clay. This difference in depth is a result of natural irregularity of the underlying rock surface.



**Figure 10.3** Sampling inside and outside of the *renvall* at Akkajärvi. Photograph by Eva Panagiotakopulu.



## **10.4 Soil profiles**

The soil profile of Column A shows a stratigraphy consisting of unhumified peat overlying a grey silty/clay deposit (Figure 10.4 and Figure 10.6). Some small inclusions of charcoal, no bigger than 5mm were present in Sample 30-35cm in Column A. The grey clay horizon was not found in the Column B samples. The soil profile from Column B shows a gradual change in conditions, from a dark brown silty clay, through increasingly less humified peat, to moss- and sedge/grass-dominated unhumified peat from 30cm (Figure 10.5 and

Figure 10.7). The remains that were extracted from these samples were well preserved, including a pubescent, articulated body of *O. nodosus*.

Darker and lighter bands, representing different degrees of humification, were observed in the soil profiles, most notably at around 15cm (Figure 10.6 and Figure 10.7). Such bands have been termed ‘recurrence surfaces’ by Granlund (1932), and may reflect climatic changes influencing peat formation (Börgmark 2005).

## **10.5 Preservation**

Preservation was good throughout the samples and included Formicidae, Acari and Diptera in addition to the Coleoptera. Each group was quantified. Identification of some of the dipterous remains has been undertaken, and the identification of possible oestrids awaits confirmation.

Low numbers of species in the upper samples of both columns do not appear to be a result of poor preservation. As will be discussed below, this seems likely to be the result of more compact peat (slower accumulation) in the lower layers and more loosely packed peat in the upper layers (faster accumulation).



**Figure 10.4** Column A sampling pit showing grey clay base at Akkajärvi.  
Photograph by Eva Panagiotakopulu.



**Figure 10.5** Column B sample pit at Akkajärvi. Photograph by Eva Panagiotakopulu.

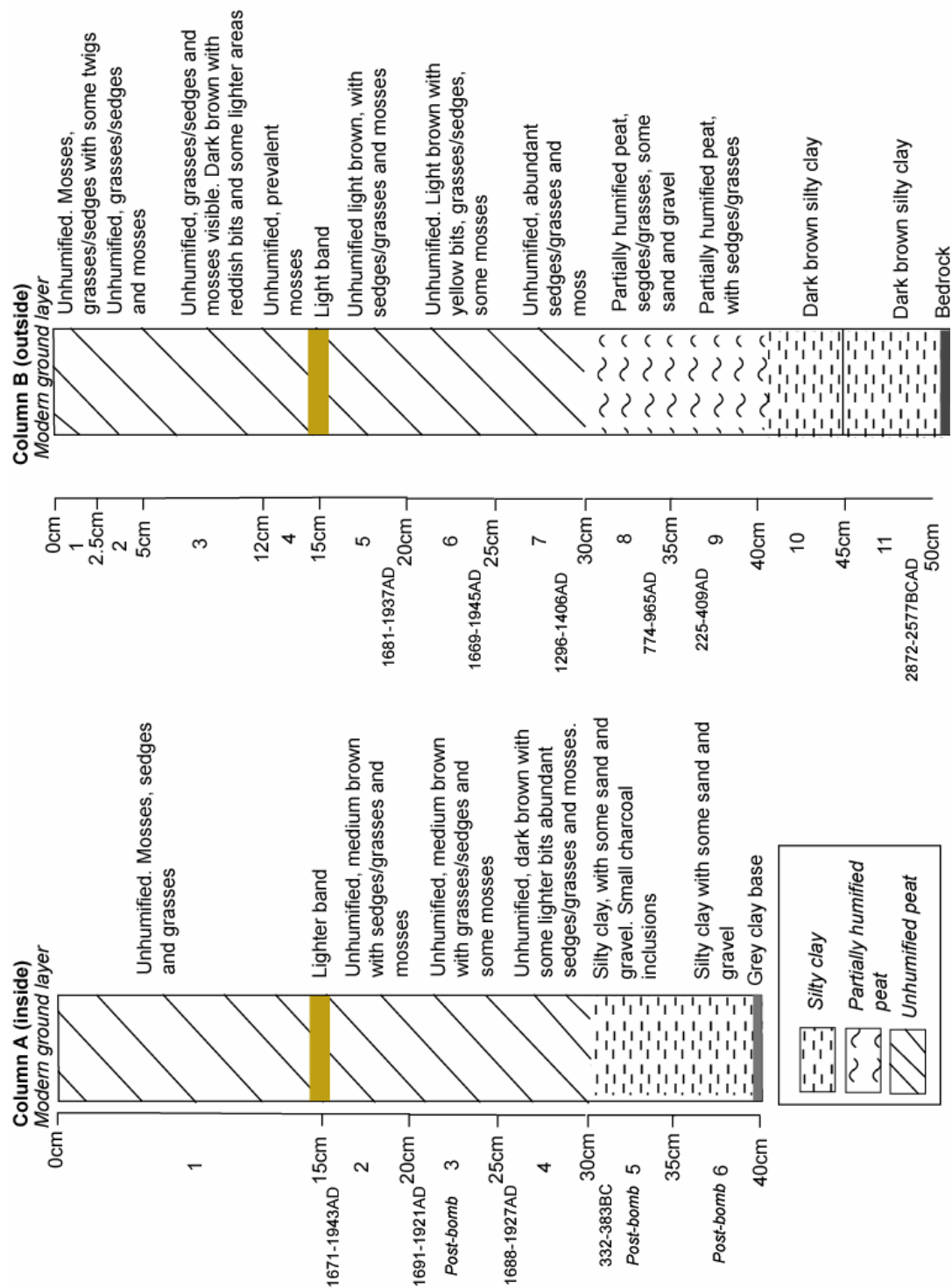




**Figure 10.6** Column A soil profile at Akkajärvi. Photograph by Eva Panagiotakopulu.



**Figure 10.7** Column B soil profile at Akkajärvi. Photograph by Eva Panagiotakopulu.



**Figure 10.8** Soil profiles of columns taken for insect analysis at Akkajärvi. Radiocarbon dates from corresponding depths of the pollen profiles are shown, with dates from insect Column A given in *italics*.

## 10.6 Dating

### 10.6.1 Column A – inside of the *renvall*

Two sets of material for radiocarbon dating from inside the *renvall* were taken, one from the insect sample site and the other from the pollen monolith. The difference in the depth of the two columns meant that close correlation between the two successions was uncertain. Small fragments of mosses (*Sphagnum* and *Polytrichum*) were selected as the most suitable material from the insect sampling column. Radiocarbon dating of this material is considered to be relatively secure, with problems of contamination by younger carbon via root penetration minimised (Nilsson *et al.* 2001).

Three dates from the insect column were taken: from the basal sample (35-40cm), from Sample 5 (30-35cm) and from Sample 3 (20-25cm) (Table 10.2). The results show that the fraction modern in each of the samples was greater than 1, suggesting formation during the post-bomb period (approximately post 1950 AD).

It is possible that young carbon may have been introduced to deeper layers by root penetration of surface plants, or from the downward flux of dissolved organic carbon (Aravena *et al.* 1993; Nilsson *et al.* 2001), but this should not affect dates from mosses. The latter problem, although known to affect the radiocarbon age of gases, has not been recorded as having a drastic effect on the surrounding peat dates (Aravena *et al.* 1993; Charman *et al.* 1994). Trampling and human activities inside of *renvall* could have disturbed the ground, resulting in mixing of the upper layers. Nevertheless, the material from the adjacent pollen core has not been affected by such modern contamination or post depositional factors (Table 10.3), and the aberrant results may be explained by either the incorporation of modern surface moss which is unlikely, or laboratory problems.

Although the dates from the pollen core cannot be extrapolated onto the insect column directly, they do provide some indication that the modern values from the insect column should be considered with caution. The date of 522-383 BC from charcoal at 30-31cm is

over 2000 years older than the date taken only 5cm above in the profile. This could suggest that this charcoal is not *in situ*, or could be explained by extremely slow accumulation rates during this time.

### 10.6.2 Column B – outside of the renvall

Correlation between insect and pollen cores outside of the *renvall* means that radiocarbon dates obtained from the pollen cores in this location (Profiles B and C) should be applicable to the discussion of the insect fossil remains, and no additional dates were obtained. Profiles B and C were taken from overlapping sections of the same peat column.

The dates taken from macrofossil remains (*Sphagnum* mosses and a *Betula* twig) and humic acid provide a range from 2872-2577 BC from the basal sample, to 1681-1937 AD at a depth of 19-20cm (Table 10.1). Dating of a *Betula* twig, a short lived species, is preferable to long-lived species and heartwood from trees, which may be much older than the sample from which they came (Bowman 1990). Humic acid can be more problematic for radiocarbon dating, with the transport of soluble organics through the sediment sometimes resulting in dates which are erroneous (Shore *et al.* 1995).

Depth	Material dated	Uncalibrated date (BP)	Calibrated age with 95.4% probability (2 $\sigma$ )	Lab Code
AKK-C	<i>Sphagnum</i> sect.	105 $\pm$ 30	1681AD-1937AD	SUERC-27808
19-20 cm	<i>Acutifolia</i>			
24-25cm	Peat (humic acid)	140 $\pm$ 30	1669AD-1945AD	SUERC-34237
28-29 cm	Peat (humic acid)	605 $\pm$ 30	1296AD-1406AD	SUERC-27809
33-34cm	Peat (humic acid)	1175 $\pm$ 30	774AD-965AD	SUERC-34238
36-37cm	Twig <i>Betula</i>	1705 $\pm$ 30	255AD-409AD	SUERC-34239
AKK-B	Peat (humic acid)	4120 $\pm$ 35	2872BC-2577BC	SUERC-34236
49-50cm				

**Table 10.1** Radiocarbon dating results from samples taken from pollen cores outside of the *renvall* at Akkajärvi. Profiles B and C were taken from overlapping sections of the same peat column.



Depth	Material dated	Fraction Modern Fm	Calibrated Age with 95.4% probability (2 $\sigma$ )	Lab code
20-25 cm	<i>Polytrichum</i> sect. <i>Polytrichum</i>	1.0503 $\pm$ 0.0039 fraction modern	Post-bomb	SUERC-34065 (GU-23796)
30-35cm	<i>Sphagnum</i> sect. <i>Acutifolia</i>	1.0018 $\pm$ 0.0036 fraction modern	Post-bomb	SUERC-36757 (GU-25293)
35-40cm	<i>Sphagnum</i> sect. <i>Acutifolia</i>	1.0637 $\pm$ 0.0039 fraction modern	Post-bomb	SUERC-34069 (GU-23797)

**Table 10.2** Radiocarbon dating results from insect fossil samples taken inside of the *renvall* (Column A) at Akkajärvi.

Depth	Material dated	Uncalibrated date (BP)	Calibrated Age with 95.4% probability (2 $\sigma$ )	Lab Code
AKK-D 15-16cm	<i>Sphagnum</i> sect. <i>Acutifolia</i>	135 $\pm$ 30	1671AD-1943AD	SUERC-34243
20-21cm	<i>Sphagnum</i> capilifolium	65 $\pm$ 30	1691AD-1921AD	SUERC-34244
25-26cm	<i>Sphagnum</i> sect. <i>Acutifolia</i>	85 $\pm$ 30	1688AD-1927AD	SUERC-34245
30-31 cm	Charcoal (unknown species)	2360 $\pm$ 30	522BC -383BC	SUERC- 27810

**Table 10.3** Radiocarbon dating results from samples taken from pollen Column D, inside of the *renvall* at Akkajärvi.

## 10.7 Results

### 10.7.1 Column B

An abundance of aquatic beetles in the lower part of the sequence (Samples 8-11) includes *Hydroporus* cf. *nigrita* found in both small stagnant pools and slowly moving water (Nilsson and Holmen 1995). *Bidessus grossepunctatus* Vorbr. is a small Dystiscid

that inhabits mossy carpets of associated water bodies (Nilsson and Holmen 1995). Individuals of the genus *Enochrus* are confined to the lowest samples of the sequence, the adults often found feeding on decaying detritus in and around bog pools (Foster 2000).

Vegetation of sedges, mosses and marsh plants are the most common habitat of the moisture loving *Bembidion transparens* (Lindroth 1963; Lindroth 1985). *Limnobaris dolorosa* (Goeze) is typically found on rushes and sedges in fens and bogs (Koch 1992). Damp *Sphagnum* moss is a favourable habitat for *Bryaxis bulbifer* (Reich.) in wetland localities, although it is also known from woodland (Koch 1989ab; Atty 1983; Lott 2003). Other damp moss and litter dwelling species include *Euaesthetus ruficapillus* (Lac.) found in marshes and fens (Duff 1993; Lott 2003). *Stenus* sp. is restricted to the two lowest samples. Many of the northern species are hygrophilous, found among vegetation by water bodies, beneath scrubby woodland and within bogs (Backlund 1945; Böcher 1995).

The moisture loving Carabid *Pterostichus diligens* (Sturm) is a typical wetland species, common in fens, marshes and bogs amongst moss and litter (Lindroth 1974; Koch 1989a; Lott 2003). However it is also found in areas of wet grassland and heaths in the Faroe Islands (Bengtson 1981) and in the uplands of Britain (Luff 1998). In Sweden it has been found in woodland localities (Backlund 1945). *Lathrobium terminatum* occurs firstly in the basal sample, and reaches a peak (15 individuals) in Sample 8; it is a species typical of wetland biotopes and occasionally occurs in the leaf litter of *Salix* scrub (Brundin 1934; Lott and Anderson 2011).

In the north Atlantic region, *Patrobus septentrionis* Dej. is primarily a hygrophilous species, although it is less so in its mountain range (Larsson and Giga 1959; Lindroth *et al.* 1973; Lindroth 1974; Böcher 1988). Lindroth (1945) has discussed its prevalence on homefields in Scandinavia, while in the alpine zone, heaths and meadows are common habitats (Böcher 1988).



The adults and larvae of *Rhyncolus ater* bore into the rotting wood of both deciduous and coniferous trees (Koponen and Nuorteva 1973), and it is the sole representative of wood-related habitat in the vicinity of the sampling location at this time.

The number of individuals and diversity of species increase in Sample 9 and culminate in Sample 8. *Hydroporus* cf. *umbrosus* is particularly prevalent in richly vegetated lake and pond margins (Nilsson and Holmen 1995), and *H. morio* prefers sparsely vegetated pools as well as mossy bogs and marshes (Böcher 1988; Nilsson and Holmen 1995). Identification of the subfossil *Agabus* elytron proved difficult in the absence of other diagnostic parts. These beetles have a general tendency towards stagnant water bodies and damp biotopes (Nilsson and Holmen 1995). *Ochthebius minimus* (F.) is found in both standing and running water, from muddy banks and aquatic vegetation (Cuppen and Nilsson 1991; Merritt 2006).

*Tachyporus transversalis* Grav. resides amongst the mosses and sedges typical of richly vegetated bogs (Koch 1989a). *Philonthus* cf. *nigrita* (Grav.) is known from moss-rich wetlands (Backlund 1945; Lott 2003). The wetland environment also provided conditions for the weevil *Notaris aethiops* (F.), found particularly amongst sedges and grasses on which it feeds (Koch 1992; Bullock 1993).

The staphylinid *Acidota crenata* is found in moss and sedges in forests and bogs of lowland areas, while in the mountains it is found beneath leaf litter and stones (Campbell 1982). It is also recorded in Iceland from the proximity of lakes and from drier grasslands (Larsson and Gígja 1959). *Olophrum rotundicolle* is principally a species of riparian habitats at the edges of lakes, streams and boggy land, where it resides amongst the vegetation of mosses, sedges, shrubs and deciduous leaf litter (Campbell 1983; Böcher 1995). At higher elevations, meadows are the more common habitat (Böcher 1995).

Species tied more specifically to woodland include the leaf beetle *Cryptocephalus labiatus* (L.) which feeds upon herbs and young trees, particularly in birch, hazel and oak in woodland margins, on heaths and in bogs (Koch 1992; Bullock 1993). *Pinus sylvestris* is the main host of *Ips sexdentatus* (Boern.), although it is occasionally found upon *Picea abies*. It seeks out the thick bark of trees in various conditions and is also found on cut logs (Lekander *et al.* 1977). It seems that this species is restricted to colder climates, and is not commonly found south of the Arctic Circle today (Lekander *et al.* 1977), although records of it as far south in Sweden as Scane are known (Gustafsson 2005).

Species indicative of drier patches of ground are present from Sample 9. These include the grassland species *C. melanocephalus*, typical of drier biotopes where it resides principally in grassland and meadow vegetation (Lindroth *et al.* 1973). It prefers open habitats and has been recorded from cultivated land and heath areas (Bengtson 1981; Koch 1989a; Duff 1993). Moss-rich heaths, often in dry, sometimes sandy areas (Böcher 1988), seem a favourable habitat for *Byrrhus fasciatus* (Forst.). *Amara* cf. *lunicollis* Schiödt is attracted to areas of dry, open ground, peaty or sandy areas, often in *Calluna* heath or grass meadow vegetation (Lindroth 1986). The blunted hind angles of the thorax set this apart from many other species and the thorax also shows distinct linear foveae characteristics of *Amara lunicollis* (Luff 2007). However, the absence of other diagnostic means that identification remains tentative.

*Eucnecosum* cf. *brachypterum* is similarly known from meadows and heaths in the north Atlantic (Brundin 1934; Bengtson 1981), although it has been recorded from leaf litter in *Alnus* and *Salix* stands in the northern boreal forest (Campbell 1984) and from mossy bogs in Britain (Harde 1984; Lott 2003). Although often in proximity to streams and lakes and in moist localities (Campbell 1984), it has also been found in dry areas of heath (Østbye and Hågvar 1996). *Dyschirius globosus* (Hbst) is adapted to a range of open, damp habitats across Europe from the lowlands to high mountain regions and is

found in heathlands, meadows and bogs, amongst decaying plant litter and mosses (Lindroth 1974; Koch 1989a; Coulson *et al.* 1995; Fedorenko 1997).

Species of *Altica* can be found in association with wetlands and freshwater, and also from heaths, meadows and woodland margins and is generally found in open areas of ground (Koch 1992). Of the species most commonly found in Norrbotten today, many are found in heaths rich in *Calluna vulgaris* and *Erica* spp. (Bullock 1993; Duff 1993). The weevil *Otiorhynchus nodosus* appears for the first time in the sequence in Sample 8. This polyphagous species feeds on a range of herbs, shrubs and trees (Böcher 1988; Koch 1989ab). It resides mainly in open localities in vegetated bogs, heaths and patchy woodland stands (Koch 1989ab). The elaterid *Sericus brunneus* (L.) is recorded from *Betula* and *Salix* in Sweden, often on heathland scrub (Brundin 1943), and it has also been found in forest meadows and damp heaths (Koch 1989ab; Duff 1993).

Only one aquatic species of *Hydroporus* was found from Sample 7. *D. globosus*, *E. brachypterum*, *Altica* sp and *O. nodosus*, remain, each able to inhabit a range of environments but generally typical of quite open localities. Three individuals of *Cantharis figurata* were recovered, a species found in damp grasslands near to lakes and rivers, as well as in peaty bogs and swamps (Koch 1989ab; Duff 1993). The moss dwelling species *B. bulbifer* and *T. transervalis* were recovered alongside the eurytopic, largely wetland species *P. diligens*, while many of the damp litter and heathland indicating beetles disappear. *Eusphalerum* cf. *lapponicum* (Mann.), is a species found in wetlands, on flowering plants and within *Carex* grasses (Lindroth 1935), and is present in Sample 6. Open, dry areas are again indicated by *C. melanocephalus*. *Phyllobius maculicornis* Germ. feeds on deciduous trees (Duff 1993; Morris 1997), showing a preference for young birch trees in Finland (Austarå *et al.* 1984). Despite its dependence upon trees, it has been found in open areas on solitary trees (Palm 1996).

Species numbers decline further from Sample 5. All but one aquatic beetle suggests that pools are present but are not a prominent feature of the environment. *O. rotundicollis*, *L.*

*terminatum* and *E. brachypterum* all occur amongst damp meadow or bogland vegetation. Sample 4 includes only *P. diligens*, *Agabus* sp. and *L. terminatum*. The species of *Gabrius* in Sample 3 is tentatively identified as *G. appendiculatus* based on the small size, and the shape and punctuation of the head and elytra (Lott and Anderson 2011); however, in the absence of genitalia this is difficult to identify with confidence. This species is found primarily in grassland vegetation and damp litter. It has also been recorded from dung (Koch 1989a; Duff 1993). Other members of the genus are found in a range of damp woodland, wetland and grassland localities (Koch 1989a; Lott 2003).

In Sample 2 *E. brachypterum* returns after a brief absence, while the uppermost sample has four individuals including *Quedius boops* (grp.) (Grav.) *Mycetoporus* sp., *O. nodosus* and an unidentifiable elaterid head.

### 10.7.2 Column A

This column, taken from inside of the modern *renvall*, is shallower in depth than the column from outside, reaching only 40cm. The two lowest samples are rich in insect fossil remains and include a wealth of species found in damp heath and bog environments, as well as some with associations with wood and trees. In contrast to Column B, the aquatic fauna is restricted, and includes single individuals of *Hydroporus* sp.

*Eucnecosum* cf. *brachypterum* is prevalent, and alongside *O. nodosus* and *Altica* sp., may indicate open heath or meadow-like conditions. *Anthophagus* cf. *alpinus* (Payk.), not found in Column B, was recovered from the basal sample. In its northern range it is found often in *Trollius* meadow and amongst herbaceous vegetation or *Salix* litter (Brundin 1934; Østbye and Hågvar 1996). It is recorded in a range of flowers and trees in open areas of woodland and in damp grassy land (Koch 1989a; Hyman 1994). *Eusphalerum* cf. *lapponicum* is once again found, and may suggest flowering wetland plants and grasses (Lindroth 1935).

In Sweden, Brundin (1934) has recorded *Arpedium quadrum* mainly in heaths and meadows often in damp localities, while further south on the continent Koch (1989a) has found it in damper bogs. Species of *Calathus* are generally found in dry, open areas (Lindroth 1974; Koch 1989a), although in Scandinavia some species are also found in woodland (Muona and Rutanen 1994). *Notiophilus aquaticus* (L.) appears restricted to very exposed and dry conditions in Scandinavia, usually in heaths and grasslands (Larsson and Gíjja 1959; Lindroth 1985). *Gabrius* cf. *appendiculatus* Sharp, and *P. septentrionis* are present, as in Column B, species found in damp grasses and mosses (Lindroth 1974; Koch 1989a), the latter occasionally found in association with dung (Koch 1989a). The fly *Fannia canicularis* (Linnaeus) has been identified from Samples 5 and 6. It is associated primarily with decaying organic material, and with dung (Ferrari 1987; Rozkošný *et al.* 1997; Pont 2000), and common in temperate regions. The ‘lesser housefly’ is today considered as a synanthropic species (Rozkošný *et al.* 1997; Pont 2000).

The host trees of *Hylobius abietis* (L.) include *Picea* and *Pinus* spp. They feed upon the bark of young trees while dead, weakened and fallen trees provide a suitable habitat for breeding (Bevan 1987; Bullock 1993; Alexander 1994). The larvae appear to favour exposed conditions (Koch 1992) and in Finland this species has shown an attraction to woodland damaged by fire (Muona and Rutanen 1994). Five individuals of *Rhyncolus ater* were found in the basal samples, a species which is often found in rotting wood of coniferous and deciduous trees as well as in tree stumps and cut timbers (Palm 1951; Koponen and Nuorteva 1973).

From 30cm (Sample 4), a decline in species diversity is noted, echoing the pattern seen from Column B. Through the next part of the sequence the few individuals recovered are eurytopic species found in bogs, meadows and heaths which are relatively open in character. Hygrophilous *P. diligens* and *L. terminatum* remain, alongside individuals of *Quedius boops* (grp) and Aleocharinae, all likely to have been exploiting the wetland vegetation environment. *O. nodosus*, *E. brachypterum*, *Altica* sp. and *Gabrius* cf.

*appendiculatus* remain present. The assemblages are generally indicative of damp, but not wet conditions, although two individuals of *Agabus* in Sample 3 may be a sign of temporary water pools forming during this time.

Sample 2 includes *P. diligens*, *Gabrius* cf. *appendiculatus*, *Mycetoporus* sp. and *Otiorhynchus nodosus*. In Sample 1 *T. tranversalis*, *L. terminatum* and *D. globosus* again occur, each found in vegetative litter and mosses in open conditions. *B. fasciatus* is indicative of dry, open areas of ground, perhaps amongst mossy heath vegetation (Lindroth *et al.* 1973; Böcher 1988). These samples are characterised by only a few individuals.

## **10.8 Comparison between columns**

### **10.8.1 Summary of environmental change**

The Column B samples were taken from an area which began as a wet sedge- and rush-dominated fen. A basal date from the corresponding pollen core at a depth of 50cm places this part of the sequence c. 2872-2577 BC. The landscape is very open, with only one tree-dependent species found from Samples 10 and 11. Species indicative of damp mosses and leaf litter habitats increase in Sample 9, which can be dated to c. 225-409AD, and the occurrence of *C. labiatus* in Samples 7 and 8 could indicate the establishment of deciduous shrubs or trees in the environs. At the same time species indicative of drier biotopes are present such as *C. melanocephalus*, *B. fasciatus* and *A. lunicollis*. From Sample 7 (1296-1406 AD), the aquatic and hygrophilous fauna are much less diverse. The uppermost 30cm (Samples 1-5) indicate a habitat that is open and damp, but not wet. This occurs from c. 1681-1937 AD.

Column A, reaching a depth of 40cm, begins with a diverse fauna, with species indicative of open conditions, in damp moss and grassland localities, suggesting the existence of exposed areas. *E. brachypterum* is high in number, a species that can be found in a range of heath, mossy bog and leaf litter localities, and from both moist areas

in the vicinity of water bodies as well as drier areas (Brundin 1934; Bengtson 1981; Campbell 1984; Østbye and Hågvar 1996). Considered alongside the other taxa recovered, including *Calathus* sp., *Notiophilus aquaticus*, *Arpedium quadrum*, *Anthophagus* cf. *alpinus*, *Eusphalerum* cf. *lapponicum*, *Gabrius* cf. *appendiculatus* and *O. nodosus*, the character of the assemblage clearly indicates an open bog/heath. At the same time, beetles tied to wood are present, and include *H. abietis* and *R. ater*, species often found in dead or damaged wood (Palm 1951; Koponen and Nuorteva 1973; Muona and Rutanen 1994).

The dating of Column A has been problematic. From the insect core, a modern date is returned from the basal sample of Column A, which has been disregarded as unreliable. From the pollen core, a date of 522-383 BC from charcoal at 30-31cm is over 2000 years older than the date taken only 5cm above in the profile, and must be regarded with some caution. A date of 1688-1927 AD from 25-26cm offers some guidance to the age of Sample 4 (25-30cm), where species that are found in more richly vegetated and moss-rich habitats disappear, including *T. transversalis*, *B. bulbifer* and *A. crenata*. This may indicate that mosses and vegetative litter were reduced from this time.

Column A has fewer numbers of individuals than Column B. However, after the decline in species numbers occurring in Column B at Sample 7 (25-30cm), the contrast in number of species and individuals between the columns is not so marked. The assemblages from Column A and B are also similar in species composition from this point. In Column A, *Anthophagus* cf. *alpinus*, *Gabrius* cf. *appendiculatus*, *Otiorhynchus nodosus* and *Altica* sp. remain, taxa indicative of open, damp and perhaps grassy areas, with limited numbers of moss and litter dwelling species. All but *Anthophagus* cf. *alpinus* similarly occur in samples from Column B over the same depth. The occurrences of *Agabus* in Sample 3 (20-25cm) in Column A and Sample 4 (12-15cm) in Column B may be some indication of fluctuating levels of wetness over this time. A lighter band of peat occurs around 15cm in both columns, possibly indicating wetter conditions across the site (Börgmark 2005).

Both profiles demonstrate unhumified material overlying the silty clay base. However, Column A reaches a base of grey-silty clay at 40cm, while peat extends to a depth of 50cm in Column B before hitting bedrock. The differences in the insect assemblages and soil profiles at this time may be a product of differences in the natural development and hydrology across the site. From Sample 9 (35-40cm) in Column B there is a change to less humified peat, and a corresponding reduction in aquatic fauna and increase in heath and drier ground. This occurs around the early-Mid-1<sup>st</sup> millennium AD. At this time there is evidence that some shrubs or small trees may have been growing in the area, with an increase in leaf-litter species and the presence of tree-dependent *C. labiatus*. Warm conditions in the early centuries AD, followed by a severe cold period c. 500AD, are known from northern Sweden (Grudd *et al.* 2002). Such fluctuations in climate may have influenced changes in hydrology and vegetation at the site, encouraging the change from fen to bog.

In Column A, the assemblage indicates that the early environment is open and damp but not wet, with heath/bog vegetation, and is somewhat different in character to that seen in the lowest samples from Column B. However, as it has not been possible to correlate the two columns, it is not possible to say whether these different environments were co-occurring.

### **10.8.2 Cluster Analysis**

Cluster analysis was carried out with Ward's method, using squared Euclidean distances to construct a hierarchical clustering. This method is recommended by Perry (1986, 33), and was selected for use here as deemed more appropriate than clustering based on similarity coefficients which can be more easily led by variations in sample size/abundances. Ward's method of clustering differs to the clustering based on similarity indices, as clusters are based on minimising the within cluster variance i.e. it uses an analysis of variance to determine distances between clusters (Ferreira and Hitchcock 2009; Hammer 2009).



Four clusters result:

Cluster 1: A5, 6 (30-40cm) and B8 (30-35cm)

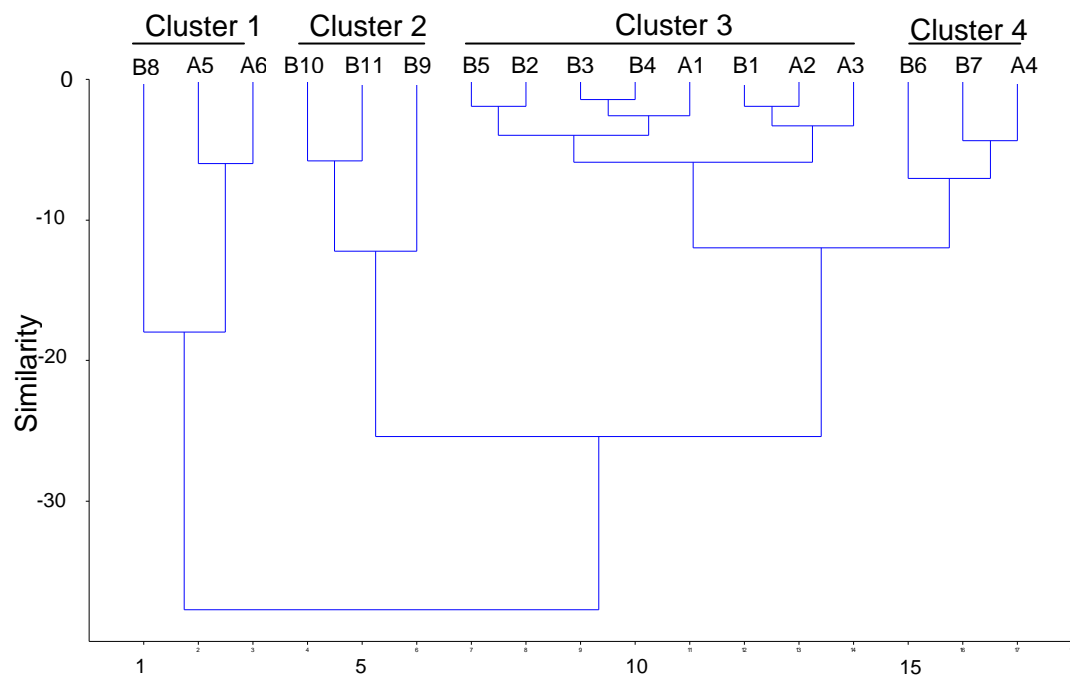
Cluster 2: B9, 10, 11 (35-50cm)

Cluster 3: A1, A2, A3 (0-25cm) and B1, 2, 3, 4, 5 (0-20cm)

Cluster 4: A4 (25-30cm) and B 6, 7 (20-30cm).

<b>Column A</b>		<b>Column B</b>
0-15cm (A1)	CLUSTER 3	0-2.5cm (B1)
15-20cm (A2)		2.5-5cm (B2)
20-25cm (A3)		5-12cm (B3)
		12-15cm (B4)
		15-20cm (B5)
25-30cm (A4)	CLUSTER 4	20-25cm (B6)
		25-30cm (B7)
30-35cm (A5)	CLUSTER 1	30-35cm (B8)
35-40cm (A6)	CLUSTER 2	35-40m (B9)
		40-45cm (B10)
		45-50cm (B11)

**Table 10.4** Results of cluster analysis on the faunal assemblages from Akkäjarvi using Ward's method.



**Figure 10.9** Results of cluster analysis on the faunal assemblages from Akkajärvi using Ward's method.

Cluster analysis shows clustering between samples of the same depth in both columns to a depth of 35cm (Clusters 3 and 4, Table 10.4). The lowest samples from Column B (Samples 9, 10 and 11) are clustered together, with no associations with Column A. The evidence from cluster analysis clearly reflects the patterns observed through a qualitative analysis of the insect fossil evidence.

### 10.8.3 Reindeer herding

The site is remembered by a local herder as an area where reindeer were gathered for milking before the change to extensive herding (Aronsson 1991, 94). *Renvall* often have a long history of use, as Aronsson (1991) has demonstrated in his palaeoecological studies of reindeer herding sites in northern Sweden, with evidence that some may have been utilised over the last 2000 years. It may therefore be considered that human exploitation of Akkajärvi has involved differing land use across the site, creating the differences in soil profiles and insect faunal assemblages from the lowest part of the columns.

Activities involved with settlement and reindeer herding could have altered the vegetation and hydrology. Mor humus or grass turf was often used for covering k  ta dwellings (Schefferus 1674, 83; Hicks 1993), and putting wet peat on the fires to produce smoke may have helped in keeping away insects in and around the *renvall* (Aronsson 1991). Peat cutting could have removed older layers, which could account for the differences in both the soil profiles and insect fossil assemblages in the lowest parts of Columns A and B. However cutting beneath the mor humus layer and removing large sections of the peat below is not an activity that has been recorded either ethnographically or in the palaeoenvironmental record at S  mi sites.

Alongside the species indicative of open, mossy bog/heath from Column A, several species tied to wood have been recovered, including *R. ater* and *H. abietis* in Samples 5 and 6. These species can be found in living trees, but many also exploit tree stumps, dead wood and timber. It is possible that the wood-dependent beetles reflect disturbance within the woodland as it was utilised for reindeer herding. As well as cutting down trees to provide construction timber for k  ta, *renvall* fences and smudge fires, trees may have been felled to give reindeer access to lichen (Berg *et al.* 2009) and some trees may have been left standing within the *renvall* to provide shade and a place to tie reindeer for milking (Aronsson 1991). In a study of Carabidae and Curculionidae from pairs of grazed and ungrazed sites in the subarctic mountain birch zone of northern Scandinavia, Suominen and others (2003) found that carabids were higher in grazed sites and included *Miscodera arctica*, *Notiophilus aquaticus*, *Amara lunicollis* and *Calathus melanocephalus*. The higher number of carabids in grazed plots may be related to microclimate, as many of these species dwell in open and dry localities. Some Curculionidae were found only in grazed plots including wood-dependent *Hylobius piceus* and *Rhyncolus ater*. Many of the Curculionidae found in grazed plots feed on dying and recently dead trees, perhaps indicating more weakened and dead conifers in grazed areas – caused by trampling and erosion damaging trees (Suominen *et al.* 2003). It is possible that the indications of wood-dependent species and open heath habitats

seen in Samples 5 and 6 from Column A could be connected to early use of the site by reindeer herders. The presence of *Fannia canicularis* in Samples 5 and 6 in Column A, often found in dung, as well as other forms of decaying organic matter (Ferrar 1987; Rozkošný *et al.* 1997; Pont 2000), lends some support to this hypothesis. In this context, the recovered charcoal from Sample 5 in Column A could be considered as relating to anthropogenic activity at the site e.g. the use of hearths or smudge fires around the camp. The site of Akkajärvi is recalled as an area where reindeer were gathered for milking in the early intensive herding system, prior to the 20<sup>th</sup> century, with indications of herding in the wider area from as early as the first centuries AD (Aronsson 1991; 1994).

After this point, from 30cm, the consistency of the peat suggests that accumulation may have slowed; the peat is not well compacted from 30cm in both columns, in comparison with the lower samples, and both successions share a similar decline in species number and diversity. Species inhabiting vegetative litter and mosses are lower in number from 30cm in both columns.

A reduction in vegetative litter, expansion of bare ground through trampling and erosion, and the impediment of the regeneration of shrubs and trees are environmental changes found at several sites across northern Scandinavia where grazing and trampling by groups of herbivores has affected the vegetation (Suominen and Olofsson 2000; Olofsson *et al.* 2001; Stark 2002; Suominen *et al.* 2003; Pajunen *et al.* 2008; Kitti *et al.* 2009). Studies have shown a complex number of factors affecting vegetation composition at grazed and trampled sites, including season and intensity of use, nutrient turn over and site productivity and history, and a range of abiotic factors, with resultant differences in coverage and regeneration of forage and non-forage plants (Manseau *et al.* 1996; Suominen & Olofsson 2000; Pajunen *et al.* 2008; Olofsson 2009). Several studies investigating the effects of grazing in the tundra have seen an overall pattern of a shift from dwarf shrub to grassland habitats (Manseau *et al.* 1996; Olofsson *et al.* 2001). Aronsson's (1991) study of pollen from both modern and historic *renvall* in northern

Sweden demonstrates a clear increase in Poaceae pollen, with *Rumex* also found in abundance from samples in, or close to the *renvall*. Other taxa including *Plantago*, *Epilobium*, *Juniperus* and Ranunculaceae are also considered indicators of reindeer herding activity, benefiting from the disturbed ground caused by trampling and the increased nutrients from faeces. These changes are marked only when grazing and trampling is of a certain intensity, with large numbers of herbivores and/or regular and long-term use.

These studies have been carried out in circumstances markedly different to that in and around a Forest *Sámi* reindeer herding site, often focusing on the impacts of extensive free grazing on tundra vegetation. Furthermore, many of these studies consider grazing in areas used for much longer periods than a few weeks each year. Nevertheless, that grazing and trampling by herbivores can alter vegetation composition is apparent, and can be considered alongside Aronsson's (1991) palaeoecological studies as interesting indicators of the local environmental impacts of such activities.

It is possible that a change in land use connected to reindeer herding may have contributed to the change in species composition and to the lowered number of individuals at Akkajärvi. Dating of the Column B profile places the change to an increasingly open environment seen from Sample 7 (25-30cm), beginning around the 14<sup>th</sup> to 17<sup>th</sup> century. Evidence of a reduction in vegetative litter occurs in Sample 4 (25-30cm) in Column A, similarly indicating a change in the environment occurring around the 17<sup>th</sup> -19<sup>th</sup> century. This environmental change may be connected with reindeer herding. If the evidence from Samples 5 and 6 in Column A can be regarded as indicating the presence of reindeer at the site at an earlier date, then this later environmental change may signal an intensification of use, perhaps by larger numbers of reindeer, possibly related to the expansion of reindeer pastoralism in northern Sweden since around the 17<sup>th</sup> - 18<sup>th</sup> centuries (Aronsson 1991; Lundmark 2007).

In summary, the problems with dating mean that the columns cannot be correlated. If the lowest samples from each of the columns are synchronous, then the differences in environment seen at this time may be a reflection either of natural differences in early development at the site or linked to exploitation of the two areas in different ways by early Sámi groups. The area from which Column A was taken was possibly used to corall reindeer, resulting in the more open bog/heath conditions, presence of wood species and indications of dung, including the fly *F. canicularis*. Despite the confusion relating to the lowest sections of each column, the similarities between both columns from 30cm demonstrate an open heath/bog, with the disappearance of many of the damp litter fauna and, as discussed, could indicate environmental changes caused by reindeer herding, possibly with larger herds. Again this is difficult to date, but may suggest this occurred from around the 17<sup>th</sup> century.

#### **10.8.4 Comparison with other palaeoecological evidence**

The current vegetation at places where reindeer have been driven together clearly demonstrates the flourishing of grasses (Kjellström 1983; Aronsson 1991), and the difference between the grass turf inside and the moss or dwarf shrub vegetation outside is often marked (Figure 10.10). This is supported by the findings of Aronsson (1991) who studied the modern and fossil pollen data from *renvall* sites in Norrbotten, finding a similar increase in graminoids and herbaceous vegetation in response to herding activities past and present. At Karlsson's (2006) reindeer herding sites, she also sees an increase in grasses in the pollen diagrams, although many of the other indicator species found by Aronsson (1991) are not present (Karlsson 2006, 147).

An increase in graminoid abundance with summer grazing is paralleled by Kitt and others (2009) in the tundra wetland vegetation in northern Finland, and the flourishing of grasses at grazed sites is echoed by other studies (Olofsson *et al.* 2001; Stark 2002; Pajunen *et al.* 2008).

The vegetational observations of modern pens, palynological evidence, and to some extent the modern grazing studies, provide evidence that reindeer herding activities can result in a flourishing of grasses in or around a *renvall*.

At Akkajärvi moss-rich habitats are indicated by species such as *B. fasciatus* and *A. lunicollis* from Column B in Sample 8, and suggest that mosses comprised an important part of the vegetation at this time. *T. transversalis* and *B. bulbifer* are far less common from Sample 5 (15-20cm) in Column B and Sample 4 (25-30cm) in Column A. From this point onwards, many of the recovered species are fairly eurytopic such as *L. terminatum*, *G. appendiculatus* and *P. diligens*, and can be found in a variety of grass and moss rich habitats in damp bogs and heaths.

It is difficult to reconstruct the vegetation cover during this interval (upper 30cm) based on these species, most of which can be found in a variety of heath, grassy areas and mossy biotopes. However, species more restricted to moss and leaf litter habitats are now absent, and those able to exploit a wider range of biotopes remain after this point. Nevertheless, the distinctive indication of a grass- and herb-rich habitat interpreted from the pollen record from *renvall* sites, which allowed Aronsson (1991; 1994) to develop a culture-indicator package pointing towards small-scale Sámi exploitation in the boreal forest, has not been found in the insect fossil record from Akkajärvi.

Karlsson (2006) finds distinct variations in concentrations of phosphorus and organic matter inside and outside of the *renvall* at her study sites in northern Sweden, suggesting differences in activity between the two areas. Somewhat surprisingly, at three out of the four sites, the extensive soil mapping showed concentrations of phosphate-rich soil and organic matter which were higher *outside* of several *renvall*, demonstrating an increase in the accumulation of faeces and urine. She suggests that the pen itself may only have been used for limited periods of time when milking or calving were taking place, whereas the free grazing of animals outside of the pen may have been more intensive. Another explanation may be that the pens were moved around the site, and that the

concentrations of enrichment represent old penning areas, or that leaf fodder was provided adjacent to the *renvall* which may cause the animals to cluster.

At Akkajärvi the similarities between columns in the upper 30cm (approximately since the 17<sup>th</sup> century) may indicate that the method is not sufficiently spatially sensitive to pick up changes over such a small area. Alternatively, it may suggest that trampling/grazing has occurred over the entire site and was not restricted to inside of the penning area during the last few hundred years.



**Figure 10.10** *Renvall*, Najal, northern Sweden.

### ***10.9 Dung, foul and parasitic insects***

The insect community expected to be found in dung in the north temperate zone may consist not only of Aphodiinae and Geotrupidae but also Hydrophilidae, Histeridae, Staphylinidae, dung flies and Acari (Hanski 1991, 17; Hanksi and Cambefort 1991, 356-357). In a study of the insect fauna found in scattered summer reindeer dung in Finnish



Lapland, Lipkow (1992) found a range of beetles including *Aphodius*, *Proteinus altaicus* Reitt. (= *apicidens* Jans. and Sjöberg), *Deliphrum tectum*, *Eucnecosum* cf. *brachypterum*, *Oxytelus laqueatus*, *Tachinus pallipes*, and a range of Aleocharinae. Some of these taxa have been found at Akkajärvi, alongside *Gabrius* cf. *appendiculatus* which can be found in dung, although not exclusively so. Members of the genus *Cercyon* are similarly often attracted to dung and foul matter (Backlund 1945; Bocher 1988; Hansen 1987; Koch 1989a). The presence of the fly *Fannia canicularis*, could, as discussed, be related to the presence of dung, although is also found in a range of rotting vegetative matter.

Records of dung beetles are known throughout the Holocene from a range of sites in Sweden as part of the natural fauna as well as from sites of human activity (e.g. Hellqvist and Lemdahl 1996; Hellqvist 1999a; Gustavsson *et al.* 2009a, 2009b; Olsson and Lemdahl 2009a, 2009b). The lack of dung beetles found at Akkajärvi merits further consideration.

Of the three groups of dung beetles - the rollers, the tunnelers and the dwellers - it is the dwellers, particularly members of the genus *Aphodius*, which dominate in the northern zone (Hanski 1991, 75). Around sixteen species of *Aphodius* are known from this area today (Gustafsson 2005). These dwellers are distinct from the other groups in that they do not move the dung to a safer location, but live in pats where they are naturally deposited. This means it is essential for the pat to be in a suitable environment and not overly exposed to adverse conditions. The entire development of *Aphodius* species, from egg to adult, happens within the dung pats (Landin 1961; Hanski and Cambefort 1991b, 39). This takes around 5-10 weeks for most *Aphodius* species (Hanski 1991, 82), and would indicate that habitat stability is important. Dung may have been a useful source of fuel and cleared from the area, limiting the resources for dung faunal community.

The affects of soil type and vegetation cover, environmental aspects of importance to other dung beetles, seem to elude the specifications of *Aphodius* (Hanski 1991, 77). It is

the consistency and moisture content that are thought to be important in food selection (Hanski 1991, 86). Landin (1961) demonstrates the need for adults to have access to at least 25-70 times their body weight and the larvae need even more significant quantities, or they will emigrate to a more suitable location. Nilssen and others (1999) found that *Aphodius* were present in the moist summer dung of reindeer in northern Norway, dominated by *Aphodius lapponum*, and maggots of the fly *Scathophaga* sp. were also notable. In comparison, the dry and pelleted winter dung contained no specimens of either of these groups.

Beetles collected from modern surface samples were analysed by Gustavsson and others (2009b) at sites in central Halland, and the island Öland, in southern Sweden, and show a high correlation between the presence of *Aphodius* and grazing intensity. However, at six sites where grazing by cows currently takes place, no dung beetles were found. These results came from a range of site types including open fenced pastures, open groves, wooded pastures, small lagoons and ditches, all within grazed environments, some classified as sites with high grazing intensity. It is difficult to understand the reason for this lack of dung beetles in grazed environments without more information on the study sites and the nature and timing of exploitation; however it is clear from this study that although the presence of certain species may correlate well with grazing, their absence cannot be directly correlated with lack of grazing (Gustavsson *et al.* 2009b). Coprophilous species were found at both grazed and ungrazed sites (Gustavsson *et al.* 2009a). However, some were only found at grazed sites, including *Oxytelus* spp. and *Cercyon* spp. Gustavsson and others (2009b) conclude that hydrophilid and rove beetles have some value as grazing indicators, but with lower significance than the pasture specialists *Aphodius* which are strongly associated with cattle dung.

In the northern latitudes many insects become inactive from late autumn (Nilssen *et al.* 1999). Heightened activity of *Aphodius* occurs during the early summer, with only a few species active in early spring and in late autumn (Hanski 1980; Hanski 1991, 87; Gittings and Giller 1997). In southern England Hanski (1980) found peaking numbers

of *Cercyon* and *Sphaeridium* species in the pastures during summer, and more limited occurrences in early spring and late autumn. If Akkajärvi was being used outside the main summer months, then the dung fauna may naturally have been low. Akkajärvi is thought to have been a place where milking was carried out, an activity taking place in the summer and autumn (Aronsson 1991, 29). Therefore it is possible that the site was mainly utilised in autumn, during earlier periods of intensive herding.

Insect parasites known to live on reindeer in modern times include the lice *Solenopotes tarandi* and *Damalinia tarandi*, the warble fly *Hypoderma tarandi* and the throat bot *Cephenemyia trompe* (Oksanen 1999). Insect harassment is known to be highest in summer, when temperatures are higher (Skarin *et al.* 2004).

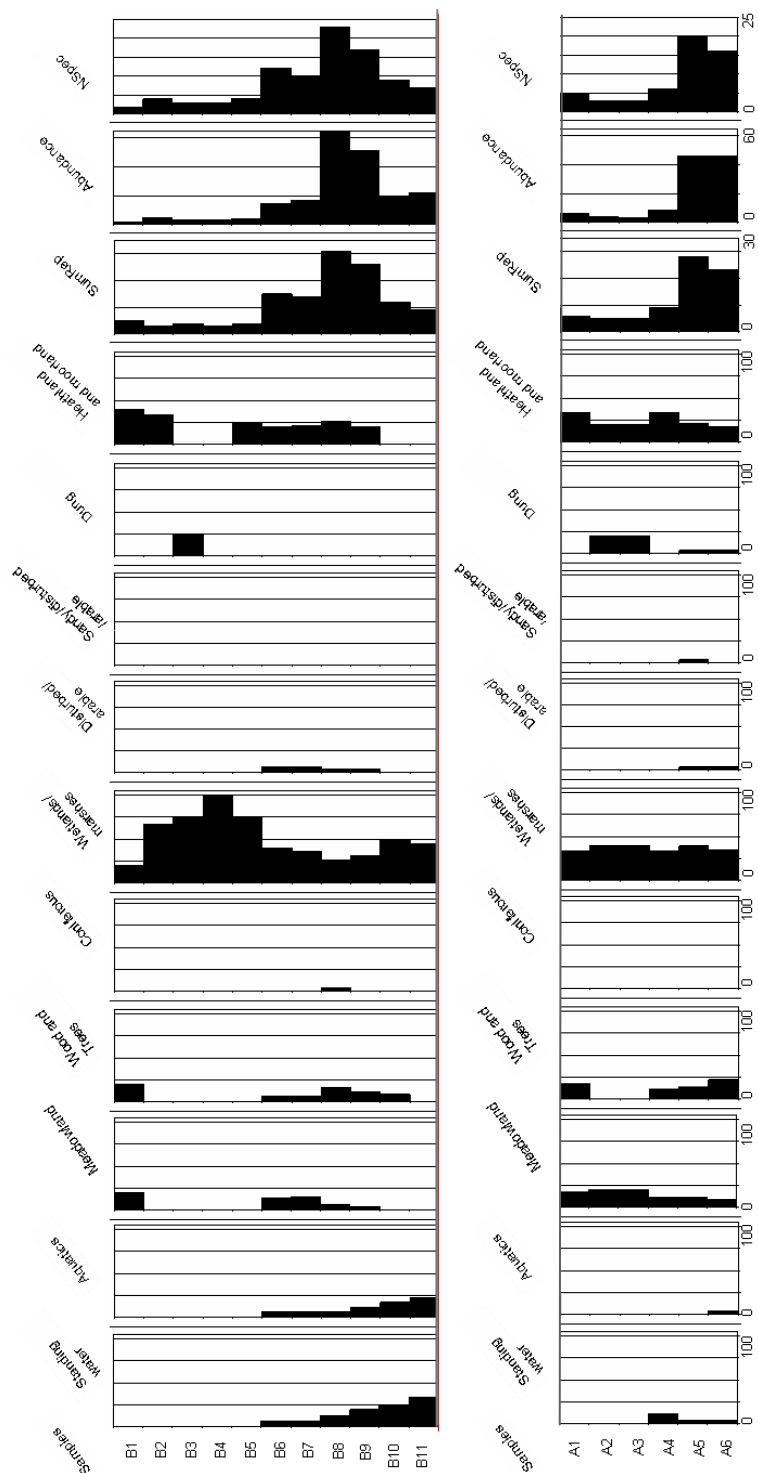
The presence of possible Oestridae in the Akkajärvi insect faunal material is waiting to be confirmed by comparison with modern material. The two oestrid fly species that are parasitic on reindeer are the warble fly (*Hypoderma tarandi*) and the throat bot fly (*Cephenemyia trompe*) (Oksanen 1999).

During the summer the female warble flies lay eggs on the reindeer, and the larvae are firmly planted within the reindeer host for much of the year, dropping to the ground to pupate in spring (Oksanen 1999). Techniques of avoiding infection include moving the reindeer away from the site where larvae were dropped to pupate in spring, thereby avoiding the later emergence of adult flies who will lay eggs on the reindeer (Hadwen 1926; Saval'ev 1968). In their study of reindeer herds in northern Norway, Folstad and others (1991) show that migration away from spring/summer calving grounds may be important in controlling levels of warble fly larvae infection, similarly demonstrating that movement away from the area where larvae have fallen is a successful means of parasite control. Hadwen (1926) discusses how a herd of reindeer in Alaska is maintained free of warble flies by a similar movement. He also notes that in Lapland, where reindeer are moved regularly, the rate of infection was particularly low (Hadwen 1926). The use of smoke to keep away insects from reindeer has been reported by

(Saval'ev 1968), and evidence of smudge fires has been found around reindeer herding areas in northern Sweden (Aronsson 1991).

The Forest *Sámi* regularly moved between *renvall* – with possibly only a week or two spent at each site in the summer migration route in order to help minimise the spread of disease (Ruong 1944, 94; Manker 1968; Aronsson 1991, 94). The constant movement between *renvall* may have helped lower the level of parasitic infection (Folstad *et al.* 1991).

The insect fossil evidence discussed previously from the site of Sorsele, and the results presented here from Akkajärvi, have provided a means to analyse the insect fossil evidence from *Sámi* sites associated with different types of occupation/exploitation. This evidence can be compared with that from sites of permanent settlement, investigated in the following chapters.



**Figure 10.11** BugsEcofig. Diagram showing the abundances of species in certain habitat groups at Akkajarvi.

Sample B1: 0-2.5cm	Sample B6: 20-25cm (1669-1945AD)	Sample B9: 35-40cm (225-409AD)
Sample B2: 2.5-5cm	Sample B7: 25-30cm (1296-1406AD)	Sample B10: 40-45cm
Sample B3: 5-12cm	Sample B8: 30-35cm (774-965AD)	Sample B11: 45-50cm (2872-2577BC)
Sample B4: 12-15cm		
Sample B5: 15-20cm (1681-1937AD)		
Sample A1: 0-15cm	Sample A4: 25-30cm (1688-1927AD)	
Sample A2: 15-20cm (1671-1934AD)	Sample A5: 30-35cm (322-383BC/ <i>Post-bomb</i> )	
Sample A3: 20-25cm (1691-1921AD/ <i>Post-bomb</i> )	Sample A6: 35-40cm ( <i>Post-bomb</i> )	

Sample	B1	2	3	4	5	6	7	8	9	10	11	A1	2	3	4	5	6
Sample depth (cm)	0-2.5	2.5-5	5-12	12-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	0-15	15-20	20-25	25-30	30-35	35-40
Radiocarbon age																	
Pollen column					1681- 1937AD	1669- 1945AD	1296- 1406AD	774- 965AD	225- 409AD		2872- 2577BC		1671- 1943AD	1691- 1921AD	1688- 1927AD	332- 383BC	
Faunal list																	
Coleoptera																	
Carabidae																	
Carabidae indet.	1	1	1							1				1			1
<i>Notiophilus aquaticus</i> (L.)																	1
<i>Dyschirius globosus</i> (Hbst.)							1	1	1	1						1	2
<i>Bembidion transparens</i> (Gebler)											1						
<i>Bembidion</i> sp.											1						
<i>Patrobis septentrionis</i> Dej.						2										1	
<i>Pterostichus diligens</i> (Sturm)		1	1	1		2	1	7	3	2		2	1		1	4	5
<i>Calathus melanocephalus</i> (L.)						1		1	2								
<i>Calathus</i> sp.																1	
<i>Amara</i> cf. <i>lunicollis</i> Schiödt								1									
Dytiscidae																	
<i>Bidessus unistriatus</i> (Schränk)										2	3	3					
<i>Hydroporus</i> cf. <i>umbrosus</i> (Gyll.)										5	1						
<i>Hydroporus tristis</i> (Payk.)						1	4	4	17	5	12						1
<i>Hydroporus</i> cf. <i>nigrita</i> (F.)								2	4	1	2				1	1	
<i>Hydroporus</i> sp.								2									
<i>Agabus</i> sp.				1													
<i>Agabus</i> spp.								1						2			
Hydraenidae																	
<i>Ochthebius minimus</i> (F.)								1	1								
Hydrophilidae																	
<i>Cercyon</i> sp.								1									
<i>Enochrus</i> spp.										2	4						
Staphylinidae																	
Staphilinidae indet.						1											
<i>Eusphalerum lapponicum</i> (Mann.)							1	1								2	1
<i>Olophrum rotundicollis</i> (Sahl.)						1		1		1							
<i>Arpedium quadrum</i> (Grav.)								1								1	
<i>Eucnecosum</i> cf. <i>brachypterum</i> (Grav.)		2			1	1	2	4	1						3	11	14
<i>Eucnecosum</i> sp.						1		2	2								
<i>Acidota crenata</i> (F.)								1	3	1						1	3
<i>Anthrophagus</i> cf. <i>alpinus</i> (Payk.)																	1
<i>Stenus</i> sp.										2	1						2
<i>Euaesthetus ruficapillus</i> (Lac.)										1							
<i>Lathrobium terminatum</i> Grav.		1	1	1	1	2		15	6		1	1			1	2	
<i>Lathrobium</i> (s.l.) sp.																5	2
<i>Philonthus nigrita</i> (Grav.)						1	1	1	2								
<i>Gabrieus</i> cf. <i>appendiculatus</i>			1										2	1		2	2
<i>Quedius boops</i> grp. (Grav.)	1									1					1	2	1
<i>Quedius</i> sp.								1								2	1
<i>Mycetoporus</i> sp.	1	1						1					1				2
<i>Tachyporus transversalis</i> Grav.		1				1	1	3	3			1				2	3

Aleocharinae indet.	1				1	2	5	4	1			1		2	5	6	3
Pselaphidae																	
<i>Bryaxis bulbifer</i> (Reich.)						1	2		2	2	1					3	5
Cantharidae																	
<i>Cantharis figurata</i> Mann.							3		1							1	
Elateridae																	
<i>Elateridae</i> indet.																1	
<i>Sericus brunneus</i> (L.)								1	1								
Byrrhidae																	
<i>Byrrhus fasciatus</i> (Forst.)								1				1					
Chrysomelidae																	
<i>Cryptocephalus labiatus</i> (L.)							1	1									
<i>Altica</i> sp.						5	1	7	2			1			1	4	2
Scolytidae																	
Scolytidae indet.																1	
<i>Ips sexdentatus</i> (Boern.)								1									
Curculionidae																	
<i>Otiorhynchus nodosus</i> (Müll.)	1						1	5				1	1	1	2	2	1
<i>Phyllobius maculicornis</i> Germ.						1										1	1
<i>Rhyncolus ater</i> (L.)										1						2	3
<i>Notaris aethiops</i> (F.)								1									
<i>Hylobius abietis</i> (L.)																	1
<i>Limnobaris dolorosa</i> (Goeze)											3	2					
Hymenoptera																	
Formicidae	7	14	2	1		2	17	32	80	9	3	13	5	1	5	35	25
Diptera																	
Diptera indet.	4		3	1	2	4	9	6	5			7	4	7	7	16	12
<i>Fannia canicularis</i> L.																2	2
Acari																	
Acari indet.	21	16	30	43	25	5	100	110	47	1		43	40	1	30	110	70

**Table 10.5** Akkajärvi Faunal list.

## 11 Gammelhemmet

The study site is situated approximately 2km southwest of the modern township of Knaften in Lycksele Municipality, Vasterbötten (N 64° 25.95, E 18° 36.89). Extensive wetlands and small lakes occur within the wider surroundings, within a topography of small undulating hills. The Umeälven is located 17km to the east, while the smaller Öreälven bounds the site 800m to the west. Cultivated land occurs along much of the river today and virtually all areas of forest are intensively managed.

Located in the boreal zone, the mixed coniferous-deciduous forest of the region is dominated by Scots pine (*Pinus sylvestris* L.) whilst Norway spruce (*Picea abies* (L.) Karst.) occurs in areas of fine grained, richer soils. (Sjörs 1965; Kempe and von Segebaden 1990; Niklasson and Granström 2000). Deciduous trees include *Betula pubescens* Ehrh. and *Betula pendula* Roth, *Alnus*, *Populus* and *Salix* spp, while *Empetrum nigrum* L., *Calluna vulgaris* (L.) Hull., *Vaccinium* and *Cladina* are common components of the forest floor (Östlund *et al.* 1997).

Samples were collected from a bog situated approximately 150 metres northeast of the abandoned farm of Gammelhemmet at 264m asl. The bog surface is dominated by a dense mat of grasses and sedges, with abundant *Sphagnum* and feather mosses. A field layer of ericaceous dwarf shrubs is dominated by *Vaccinium vitis-idaea* (L.). Shrubs of *Betula nana* L. and small spruce and pine trees cover much of the bog. A thin veil of trees to the east separates the bog from the surrounding denuded landscape which has recently been clear felled. Patchy woodland prevails to the west, while to the north a few standing snags, large solitary trees and several uprooted trees are found in an area of cleared woodland.

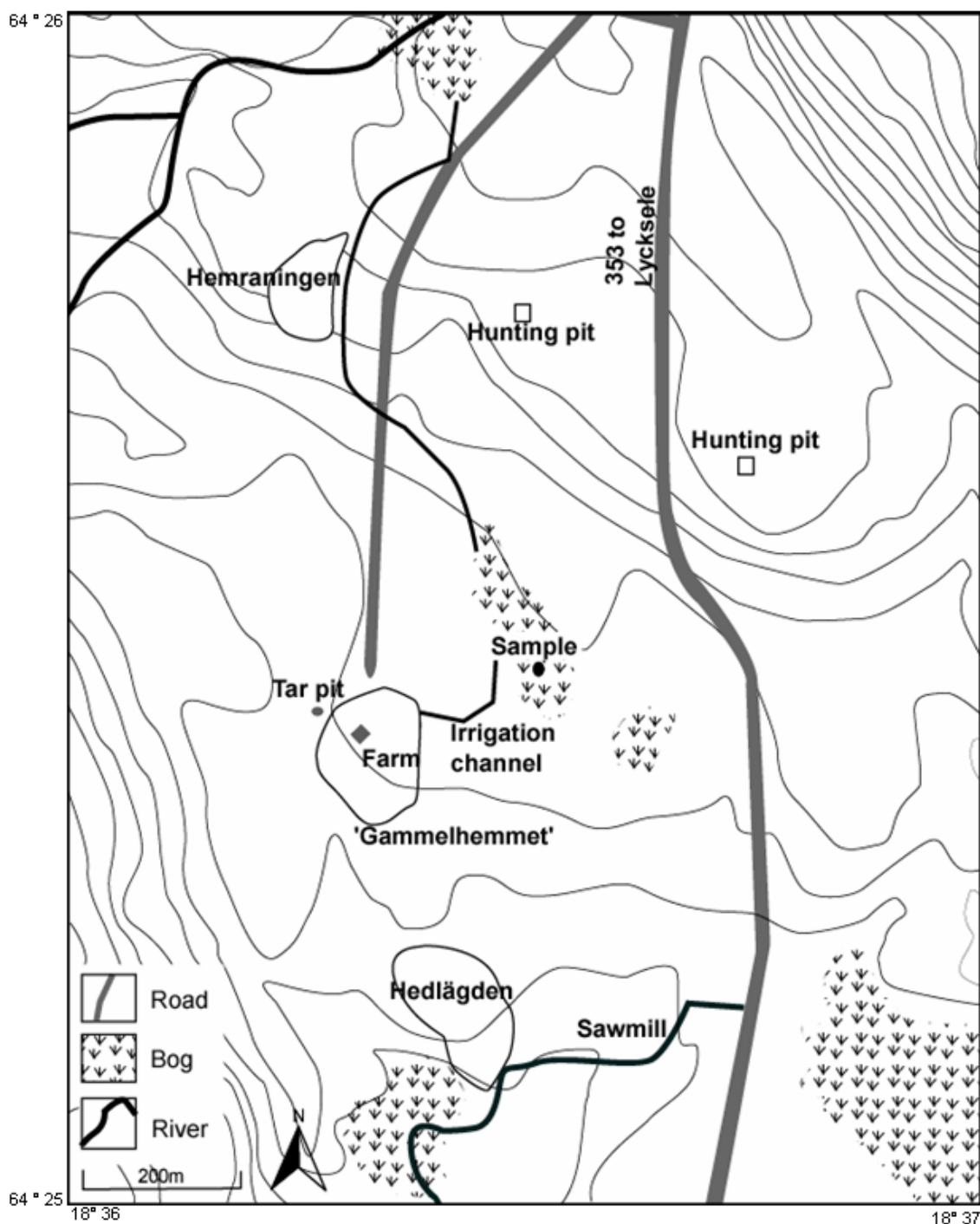
Following the downward slope of the land to the west (Figure 11.1), the old farming area is located in an area of flat land. An area roughly 200 x 150 m surrounds the remains of an old farm house, and is considered to be an ancient field for hay production and



possibly once cultivated (Riksantikvarieämbetet 2012). Forty clearance cairns and terrace ridges are recorded within this field and the remains of a wall provide a boundary. An irrigation channel runs from close to the bog where samples were taken towards the main farming area (Figure 11.1). There is no indication when this feature was initially cut. The area around Knaften is known to have been settled during the period 1701- 1749 AD (Bylund 1956), and the population records show a total of 13 people living in the area in the year 1741 (Söderholm 1973). The farm of Gammelhemmet is present on a map of 1726 AD (Lantmäteriet, map number Z16-110-1).

Two other farms are recorded in the area, the settlement remains of Hemraningen to the north and the old agricultural area of Hedlågden to the south (Figure 11.1). A saw-mill to the southeast may be connected with the farms, or with the intensification of logging in the late 19<sup>th</sup> century (Östlund *et al.* 1997; Riksantikvarieämbetet 2012). A wood tar pit possibly dates to the late 18<sup>th</sup> - 19<sup>th</sup> century when management of the woodland for potash and tar production occurred in some areas of Lycksele parish (Östlund *et al.* 1997; Nordlind and Östlund 2003).

Two hunting pits lie to the north east of the site, and more extensive pit systems exist along the Öre river. Approximately 1km to the southwest, on the opposite side of the river, a cluster of settlement remains ascribed to the Sámi have been recorded. Bronze Age burials and an undated reindeer pen are also located within a few kilometres radius of the site, along the river.



**Figure 11.1** Sample location at Gammelhemmet showing the surrounding natural environment and cultural landscape. Information from Riksantikvarieämbetet (2012).

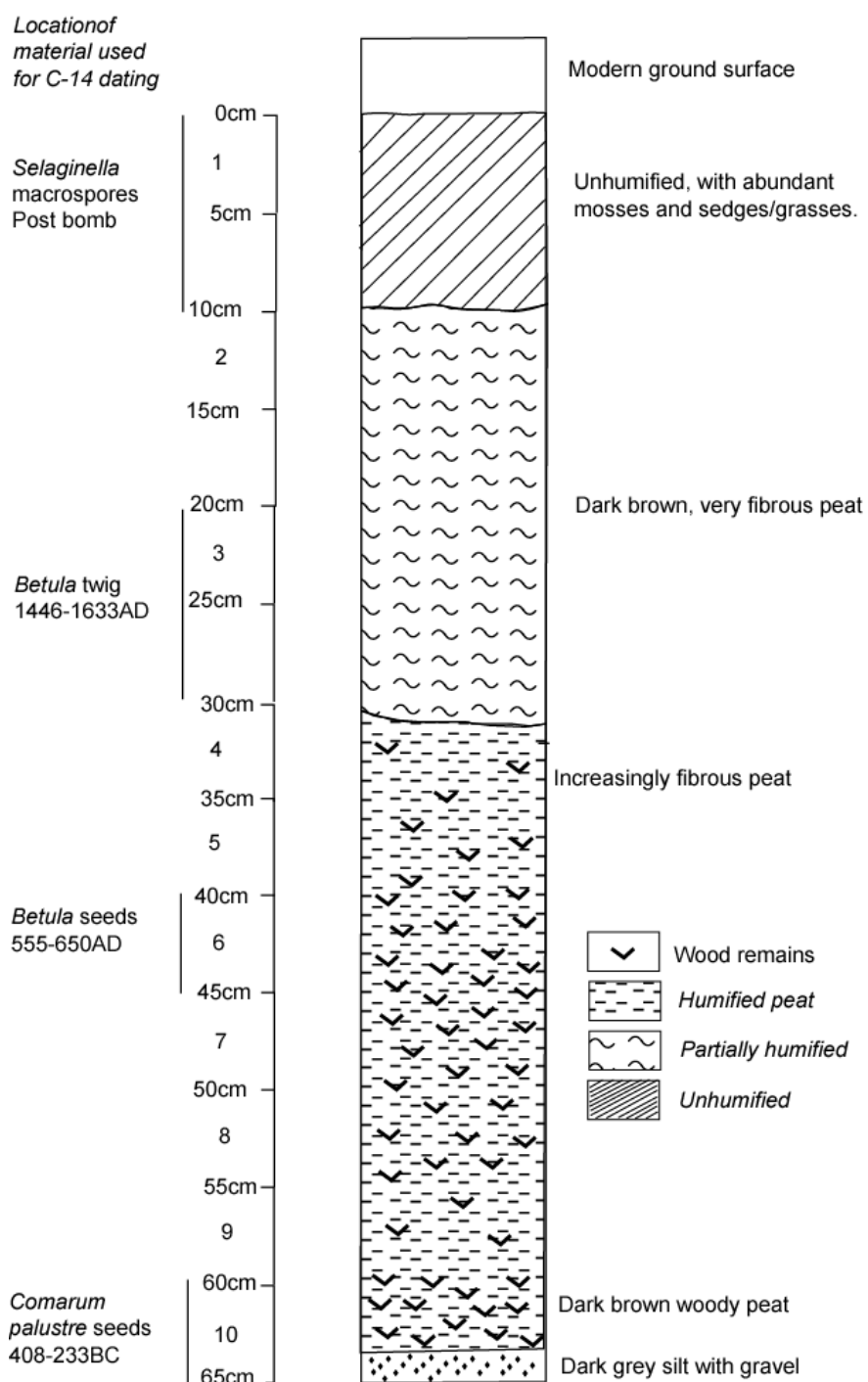
## **11.1 Methodology**

A total of 10 samples of approximately 5 litres each were taken from the side of the dug-out pit, which reached to a depth of 65cm where a silt/gravel substrate was encountered (Figure 11.2). The surface layer was removed before sampling commenced. The top 30 cm was sampled at intervals of 10cm due to the densely packed fibrous material encountered; the remaining samples were then taken at 5cm intervals.

Preservation of remains was generally good throughout the succession, however fragmentation and loss of colour in the fragile elytral remains of *Longitarsus* and *Coccinella* hindered identification to species level. In other circumstances only the elytra or thoraces of species were found, which were not diagnostic enough in themselves to permit identification of *Gabrius*, *Quedius* and *Mycetoporus* to species level. No charcoal was found in the samples.

## **11.2 Dating**

Plant macrofossil remains were extracted for AMS dating, with identified seeds, macrospores and a small twig being the preferred materials due to their short life spans. Four dates were successfully returned. A straight-forward chronological sequence is observed through the succession, beginning with a basal date of 408-233 BC from *Comarum palustre* seeds and dating of *Selaginella* macrospores from the upper 10cm suggesting formation of this sample during the post-bomb period (approximately post 1950 AD).



**Figure 11.2** Profile of column showing locations of material used for radiocarbon dating from the site of Gammelhemmet.

Depth	Material dated	Uncalibrated date (BP)	Calibrated age with 95.4% probability (2σ)	Lab code
0-10cm	Macrospores: <i>Selaginella</i> sp.	1.0658±0.0039 fraction modern	Post-bomb	SUERC- 33486
20-30cm	Twig: <i>Betula</i> sp.	375±30	1446AD-1633AD	SUERC- 33099
40-45cm	Seeds: <i>Betula</i> sp.	1455±30	555-650AD	SUERC- 33485
60-65cm	Seeds: <i>Comarum palustre</i>	2305±30	408–233BC	SUERC- 33100

**Table 11.1** Radiocarbon dating results from Gammelhemmet.

### 11.3 Results

In the basal sample, several beetles that are dependent on trees in both their adult and larval stage are present, indicating the prevalence of a woodland environment. *Deporaus betulae* (L.) feeds on the leaves of *Betula* trees and shrubs, and occasionally *Alnus* and *Corylus* (Koponen and Nuorteva 1973). The larvae develop in the leaf rolls of the named trees (Hoffmann 1954). Fen woodland and river margins are the preferred habitat of the willow beetle *Phratora vulgatissima* (L.), where it feeds on *Salix* and *Populus* in damp ground (Koch 1992; Duff 1993). Young trees in woodland clearings appear to be a favourite habitat of *Phyllobius* sp. in Scandinavia (Palm 1996).

In northern Sweden, Palm (1951) records *Rhyncolus ater* (L.) from deciduous trees, typically birch. It is a wood boring weevil which attacks trees in various states of decay, mostly in rotting wood where it creates distinctive galleries (Palm 1951; Koponen and Nuorteva 1973).

The elaterid *Denticollis linearis* (L.) further suggests the presence of a mixed forest, where it preys on the larvae of tree-dependent scolytids (Beaver 1967). It has been found

in a variety of closed forest environments on rotting and fungus infested wood (Palm 1959).

Accompanying the woodland fauna in the basal sample is a wealth of litter and moss dwelling species typical of damp habitats; these include *Olophrum* spp., *Lathrobium terminatum* Grav. and *Acidota crenata* (F.) (Campbell 1983; Duff 1993). *Olophrum consimile* (Gyll.) and *O. rotundicolle* (Sahl.) dwell amongst the litter of *Salix* scrub and alder carr and the mosses and detritus of wet bogs and stream margins (Campbell 1983; Koch 1989a; Böcher 1995). *L. terminatum* is typical of wetland biotopes and is occasionally found in the leaf litter of *Salix* scrub (Brundin 1934; Lott and Anderson 2011). In Swedish Lapland, *Acidota crenata* has been recorded from the vegetated ground layer of birch woodland (Brundin 1934). Generally, this species appears to be attracted to rotting material in damp and shaded localities (Larsson and Gígja 1959; Campbell 1982).

Well-preserved remains of the chrysomelid *Altica* sp. were recovered from Samples 9 and 10 (55-65cm). Members of this genus are found in heaths, bogs, meadows and woodland scrub, usually within relatively open conditions (Koch 1989a; Hyman 1992).

In Sample 9 staphylinids dominate the small assemblage and the previous woodland fauna is absent. *Eucnecosum* cf. *brachypterum* (Grav.) enters the sequence and remains prevalent until Sample 3. This is a rather eurytopic species found in a range of rich meadows, heaths, bogs and grasslands, in deciduous woodlands and in association with rivers and lakes (Brundin 1934; Campbell 1984; Koch 1989a). It is known from vegetative litter and under stones in range of relatively open habitats in Scandinavia (Brundin 1934; Østbye and Hågvar 1996).

*Hydroporus morio* Aubé is present, indicating the availability of stagnant pools of water (Nilsson and Holmen 1995), characterised by *Sphagnum* and *Eriophorum* (Böcher

1988). This species usually inhabits temporary pools in peaty bogs (Flint 1963; Nilsson and Holmen 1995).

Samples 7 and 8 include the rove beetles *Cryptobium fracticorne* (Payk.) and *Bryaxis bulbifer* (Reich.), common in the damp mosses and grasses of bogs, wet woodlands and riparian habitats (Koch 1989a; 1989ab). Species of *Gabrius* are present, as are *Quedius* in Sample 7. Species of *Gabrius* are found predominantly in damp localities, amongst plant debris (Backlund 1945; Larsson and Gíjja 1959). *Quedius* inhabit a diverse range of habitats and in Sweden, recorded from decaying plant material, under tree bark, on fungi and commonly in bird's nests (Palm 1951; 1959).

*Pityogenes bidentatus* (Hbst.), a common scolytid of coniferous woodlands in Scandinavia (Lekander *et al.* 1977), is the only tree-dependent species in Samples 7, 8 and 9. It is found in the branches of *Picea* and *Pinus*, often attacking the thinnest areas of bark (Lekander *et al.* 1977). *Strophosoma capitatum* (Deg.), found in Samples 4, 6 and 7, has been recorded in Scandinavia defoliating coniferous trees (Austarå *et al.* 1984), although in mainland Europe it is more commonly found in open environments amongst *Calluna*, the larvae feeding upon the roots (Koch 1992; Morris 1997). Its presence may signify the availability of both habitats at the site in order to facilitate the full life cycle of this beetle.

Sample 7 also introduces *Longitarsus* sp. to the Faunal list. Members of this genus can be found in a range of grassland, open woodlands and meadows (Hyman 1992; Koch 1992). Unfortunately only elytra were found, in a poor state of preservation, hindering identification to species level. Species currently found in the Västerbotten area include those chiefly found feeding on plants in the family Asteraceae and also on *Plantago*, often in areas of disturbed ground (Bullock 1993; Duff 1993).

The assemblage from Sample 6 includes *Hydroporus melanarius* Sturm which appears to favour peat-rich, mossy areas within woodland localities (Koch 1989a; Nilsson and

Holmen 1995; Merritt 2006). *Anthonomus phyllocola* (Hbst.) is a weevil associated with pine, the larvae developing in catkins and adults feeding upon the needles (Morris 1977; Lindelöw and Björkman 2001). It is also found occasionally on *Picea* (Koch 1992). It appears to be able to live within most types of habitat in which its host species flourish, including bogs and heaths (Koch 1992). *Cryptocephalus labiatus* (L.) is also present from Sample 5, a species which feeds primarily on *Quercus*, *Betula* and *Salix* (Koch 1992; Bullock 1993; Duff 1993). It is known from river banks, bogs and lightly wooded heaths (Koch 1992).

The staphylinid community remains stable in Samples 4, 5 and 6, exploiting the damp accumulation of mosses and litter available on the ground surface. In Sample 4 increasing numbers of *Altica* sp. and *Longitarsus* sp. are present. *P. vulgatissima* and *A. phyllocola* suggests the juxtaposition of pine woodland and *Salix* scrub. *Patrobis assimilis* (Chaud.), is generally found in relatively open localities including wet bogs characterised by sedges and *Sphagnum* mosses or drier areas of shrub-scattered heathlands with ericaceous vegetation (Lindroth 1985) is also present.

There is a distinct change in species composition in Sample 3. A stark contrast to the previously rich staphylinid fauna is notable, with only two individuals of *C. fracticorne* and *Gabrius* sp. remaining. *Otiorhynchus nodosus* (Müll.), a frequent but small component of the sequence until this point, becomes prevalent, dominating the sample. This polyphagous weevil feeds on a range of plants and is known from various environments across its range including bogs, meadows and light woodlands (Koch 1989ab). However, in the North Atlantic region its primary habitat is meadow and grassland in relatively dry localities (Larsson and Gíjja 1959; Lindroth *et al.* 1973).

*Chaetocnema hortensis* (Geoff.) is a leaf beetle which develops on and feeds primarily on Poaceae, commonly recorded in fields and meadows (Koch 1992; Lane 1992; Duff 1993). It has been found in association with *Plantago* sp. (Lane 1992), in weedy places and in arable land (Koch 1992). Forest environments and wild grasses are preferred for



hibernation, after which cereal crops and weedy areas are often sought for feeding and larval development. Wild plants may equally provide suitable hosts (Davidyan 2008). Although sometimes found in damp, mossy areas and swampy river meadows (Donisthorpe 1939; Koch 1992), it occurs mostly in drier localities (Koch 1992).

*Calathus melanocephalus* (L.) is similarly known primarily from open grasslands (Lindroth 1974; Atty 1983). Fields and meadows, including areas of cultivation, are common habitats (Harde 1984; Duff 1993; Lindroth *et al.* 1973) and in the north Atlantic it appears to favour dry and exposed areas (Larsson and Gígja 1959; Lindroth *et al.* 1973).

*Ampedus nigrinus* (Hbst.) also appears in Sample 3. It inhabits trees in varying states of decay, red-rotted and mould ridden. Old or dead trees provide a suitable habitat for the development of its larvae (Horion 1953; Koponen and Nuorteva 1973; Hunter 1977; Alexander 1994). Pine, spruce and birch are those frequently utilised (Koponen and Nuorteva 1973; Bullock 1993), often in damp boggy environments (Palm 1959). Both Koch (1989a) and Palm (1951; 1959) have commented on its prevalence in *Betula* damaged by fire.

Sample 2 produced a very low number of specimens. Aquatics *H. morio* and *Anacaena lutescens* (Steph.) are present, the latter a beetle of acidic localities including stagnant or slow moving waters (Hansen 1987; Merritt 2006). *Plateumaris discolor/sericea* (Panz.)/(L.) is present in this sample only. It feeds on the waterside vegetation of *Carex* and *Eriophorum* occurring in wet bogs (Koch 1992). *Pterostichus strenuus* (Panz.) is a shade loving Carabid primarily found in the damp ground layer of deciduous woodlands (Atty 1983; Duff 1993). It also frequents vegetated marshes and natural grassland with sufficient vegetation to provide cover (Lindroth 1945; Eyre and Luff 1990; Lott 2003). It disappears from the sequence at this point, having been present through Samples 3-8.

The staphylinid assemblage *O. consimile*, *E. brachypterum*, *A. crenata*, *L. terminatum*, *C. fracticorne* and *Quedius* sp. is present in Sample 1 alongside *Pityophthorus lichtensteini* (Ratz.), commonly found in the thin twigs and branches of pine trees (Lekander *et al.* 1977) and *Hylurgops palliatus* (Gyll.) which is known from coniferous woodland, burrowing into the bark of dead trees (Alexander 1994). In areas affected by logging, this species has been recorded within the cut logs and stumps (Lekander *et al.* 1977). Standing bog pools in which *Hydroporus* develop are present. *Agonum fuliginosum* (Panz.) makes a fleeting appearance, a species of very marshy areas where it resides amongst the shade of vegetation (Duff 1993; Lott 2003). It is also known from woodland environments where it dwells amongst ground mosses and leaf litter (Lindroth 1945; 1974).



**Figure 11.3** Under the microscope snapshot of the well preserved insect fossil remains in Sample 3, Gammelhemmet, dominated by *Otioryncus nodosus*. Photograph by author.

## 11.4 Discussion

In the basal sample of the sequence, dated to c. 320 BC, species found in old, rotting and dead wood reflect the mature woodland prevailing at Gammelhemmet. The presence of beetle species found on young trees, such as *D. betulae* and *P. vulgatissima* (Koponen and Nuorteva 1973; Koch 1992; Duff 1993), suggests that *Betula*, *Alnus* and *Salix* were growing in the lighter areas of woodland. Leaf litter and mosses comprised the damp and shaded ground layer, home to several hygrophilous staphylinids, including *Olophrum consimile*, *L. terminatum* and *A. crenata*, all of which can be found in damp and wet woodland localities (Brundin 1934; Larsson and Gíjja 1959; Campbell 1982; Campbell 1983; Lott and Anderson 2011). The assemblage reflects a multi-aged woodland with mature trees and accumulations of dead wood. Woody remains were prevalent in the soil profile from the lowest sample.

The woodland fauna diminishes in Sample 9. The area becomes more open and damp, with an aquatic element demonstrating the formation of standing water bodies, in an increasingly boggy environment. A few small shrubs and associated leaf litter may have been present. In the following samples the ground fauna diversifies with the addition of several staphylinids including *Quedius* spp., *Stenus* sp. and *C. fracticorne* exploiting the damp vegetation in the developing peat bog habitat. Represented by only one scolytid, coniferous woodland is still present but probably receding to drier areas further from the bog. *S. capitatum* may indicate that dry heathland now comprised part of the wider landscape.

The tree-dependent fauna declines as the bog becomes increasingly wet. This is followed by the appearance of species present in acidic, *Sphagnum*-dominated bog habitats, perhaps indicating the onset of paludification (Segerström *et al.* 1996; Barknekow *et al.* 2008). Such changes can be encouraged by human activity, including the deliberate removal of trees (Segerström and Emanuelsson 2002) which increases

evapotranspiration, and also by climatic changes such as increased precipitation or lowered temperature (Charman 2002).

This part of the succession can be dated to the last few centuries BC and early centuries AD. Cold and wet conditions are known to have prevailed in northern Sweden during the latter part of the 1<sup>st</sup> millennium BC, with the time around 330 BC particularly severe (Grudd *et al.* 2002). The first millennium AD was then characterised by a warm climate during the first few centuries, followed by a severe cold period at around 500 AD (Grudd *et al.* 2002). Changes in peat formation in Danish bogs, reflecting climatic changes related to colder temperatures and/or increased precipitation, are noted from around 300-550 AD, and were particularly significant around 400-500 AD (Aaby 1976). Furthermore, the soil profile at Gammelhemmet displays a change to less humified material in Sample 8, possibly indicative of wetter conditions (Börgmark 2005).

Pollen evidence from a lake deposit less than 50km to the southeast of Gammelhemmet indicates the onset of paludification, characterised by increased *Sphagnum* in the pollen record, during the colder and wetter conditions occurring in the region c. 3500 BP (Barnekow *et al.* 2008). Further increases of *Sphagnum* alongside Cyperaceae occur c. 2500 BP (Barnekow *et al.* 2008). This parallels the evidence from Gammelhemmet, however, the thermal tolerance limits of the beetles in this part of the sequence do not show any restrictions that would indicate a change in temperature.

From around the Mid-1<sup>st</sup> millennium AD the fauna indicate the development of a mosaic habitat of woodland, lightly forested bog, and patches of dry heath. Further remains of *S. capitatum* denote the existence of both coniferous woodland and *Calluna* shrubs. Many of woodland-associated species recovered from this period are found in light woodland clearings and heaths, suggesting that tree cover on the wet bog was a scattering of small shrubs and young trees, perhaps with *Salix* in the wetter, nutrient rich areas. By Sample 4 the assemblage reflects the expansion of open areas, where increasing numbers of *Altica* and *Longitarsus* can be found.

This mosaic landscape of patchy forests and drier open areas in the surroundings of the bog at Gammelhemmet contrasts with the mature woodland interpreted in Sample 10. Nearby settlement remains and the presence of hunting pits may indicate human presence in the landscape during this period, although the hunting pits remain undated. A series of dates from hunting pits in Västerbotten shows a concentration of use in the Iron Age and Viking Periods (Holm 1992) and these pits are often found in association with Sámi remains (Mulk 1994). The impacts of periodic use driving fluctuations in the tree line and the development of open grassy and herb-rich vegetation have been found at several sites where intermittent Sámi use is postulated (Aronsson 1991; Carpelan and Hicks 1995; Hörnberg *et al.* 2005; Karlsson 2006). However, there is not enough evidence in the insect fossil and archaeological record at Gammelhemmet to determine whether the mosaic landscape structure seen at this time was natural or associated with human activity.

The faunal assemblage of Sample 3 is markedly different in character from both the preceding and following samples. Species which have been prevalent in the assemblage until this point are replaced by a different faunal assemblage. The disappearance of the previous woodland fauna and leaf litter species suggests the loss of the remaining shrubs and trees from the bog surface. The environment was open, with the appearance of species that inhabit grassland communities and cultivated ground including *C. hortensis* and *C. melanocephalus*.

Considered alongside the appearance of dry grassland species and the disappearance of most of the previous hygrophilous staphylinids, the increase in numbers of *O. nodosus* may indicate an expansion of a drier habitat. It has been recorded feeding on a range of plants including *Rumex*, a plant often growing in areas of drier ground, and *Trifolium* sp., today a species of pasture and meadow environments. *O. nodosus* is flightless in its northern range, as is *C. melanocephalus* (Lindroth *et al.* 1973), suggesting that they have originated from within the immediate area. *P. strenuus* indicates that shaded conditions

existed in the tall field grasses or the margins where the cover of forest prevailed. Radiocarbon dating of a *Betula* twig from Sample 3 returned a date of 1446-1633 AD, and therefore predates the earliest recorded settlements in the area in the early 18<sup>th</sup> century (Bylund 1956). It is possible that the insect fossil evidence reflects the initiation of farming at the site at an earlier date than is historically recorded, or alternatively, that the bog was being used prior to permanent settlement in the area, perhaps by indigenous Sámi groups exploiting the area for pasture or possibly early cultivation.

The Sámi may have utilised the area, creating more open conditions which in turn provided an appealing place for incoming settlers to establish farms. A multi-proxy investigation by van der Linden and others (2008) at Lappmyran, approximately 50km southeast of Gammelhemmet, found increases in open, disturbed land and dry meadow in the pollen record from c. 1500 AD (van der Linden *et al.* 2008), indicating significant human induced environmental changes within the boreal forest at this time.

The elaterid *A. nigrinus*, a beetle attracted to but not restricted to fire damaged trees (Palm 1951; 1959; Koch 1989a), is found in Sample 3 alongside the evidence of a change in environment. In Scandinavia this species has been found both in natural Holocene forest deposits (Koponen and Nuorteva 1973; Olsson and Lemdahl 2009a), and in Late Holocene samples associated with human activity (Olsson and Lemdahl 2009a). Its presence in this part of the sequence at Gammelhemmet could be related to human exploitation of the forest, possibly using fire. Burning to clear land has been indicated in the palaeoecological evidence from Dalarna, northern Sweden during establishment of a grazing shieling (Segerström *et al.* 1996). Farming practices seen throughout Scandinavia, including pasture management and crop production (Segerström *et al.* 1996; Östlund *et al.* 1997; Segerström and Emanuelsson 2002), spreading of farm waste as fertiliser (Viklund 1998) and peat cutting (Lundberg 2002) are not explicitly suggested by the insect fossil evidence at Gammelhemmet. The irrigation channel running from close to the bog towards the main farming area may have been in use during this period, affecting the hydrology of the bog. However, the

manipulation of water levels within Västerbotten is generally considered a product of the 19<sup>th</sup>-20<sup>th</sup> centuries, in connection with drainage to aid forestry or to provide irrigation systems for farming (Söderholm 1973; Zachrisson 1976; Östlund *et al.* 1997).

The few specimens recovered from Samples 1 and 2 indicate the environment began to revert to a wet bog. The staphylinid community reappears after a brief disappearance in Sample 3, in which only *C. fracticorne* remained. Aquatic fauna return alongside *P. discolor/sericea*, indicating the formation of standing water bodies in a wet bog. In Sample 1 the terrestrial ground fauna expand in the diversifying wetland habitat and indicate a moss carpet interspersed with sedges and grassy hummocks. *H. morio* accompany peaking numbers of *A. lutescens*, revealing that the ground surface became increasingly waterlogged. The natural wetland flora and fauna began to reinstate themselves during this time, although the tree and shrub layer remained sparse. This may reflect the cessation of exploitation of the area, allowing the return of the wetland fauna at this time. The historic records suggest that the site was abandoned due to severe frosts in the early 1800s when the settlers were re-located to the modern village of Knaften (Riksantikvarieämbetet 2012). A cold and wet climate is known to have prevailed at this time, at the tail end of the Little Ice Age in northern Sweden (Kullman and Kjällgren 2000; Cowling *et al.* 2001; Grudd *et al.* 2002).

Three scolytid species are present in Sample 1, denoting the existence of pine- and spruce-dominated woodland; small trees perhaps re-colonised the bog. In their study of the beetles in the dead wood of primeval and managed woodlands in Finland, Väisänen and others (1993) recorded *H. palliatus* in abundance in the managed forest only, and across Scandinavia this species has been found not only in standing trees but also in areas of logging (Lekander *et al.* 1977). Its presence in Sample 1, alongside other wood dependent species, may reflect the recent forestry practices in the area. The insect fossil record suggests that *Betula* does not feature significantly in the forest at this time. The decline in deciduous species and prevalence of even-aged, single-storied, pine- and spruce-dominated forest is a pattern known from the region as a result of modern

forestry practice over the last 100 years (Östlund *et al.* 1997). It is evident that human activity, including the effects of recent forestry practices, has shaped the woodland around the site today.



Sample number	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Sample depth (cms)	0-10	10-20	20-30	30-35	30-35	40-45	45-50	50-55	55-60	60-65
Radiocarbon age	Post-bomb		1446-1633AD			555-650 AD				408-233 BC
Faunal list										
Coleoptera										
Carabidae										
Carabidae indet.						1				
<i>Patrobus assimilis</i> Chaud.					1					
<i>Pterostichus strenuus</i> (Panz.)				1	1	1	2	2	1	
<i>Calathus melanocephalus</i> (L.)				1						
<i>Agonum fuliginosum</i> (Panz.)		1								
Dytiscidae										
Dytiscidae indet.			1							
<i>Hydroporus morio</i> Aubé		4	1					1	2	1
<i>Hydroporus melanarius</i> Sturm						2	1			
<i>Hydroporus</i> sp.					2	4	3			
Hydrophilidae										
<i>Anacaena lutescens</i> (Steph.)		3	1							
Staphylinidae										
<i>Olophrum consimile</i> (Gyll.)		1							2	1
<i>Olophrum rotundicolle</i> (Sahl.)			1		3	1	1	1	1	3
<i>Eucnecosum</i> cf. <i>brachypterum</i> (Grav.)		2			4	2	2	2	1	1
<i>Acidota crenata</i> (F.)		1				1				2
<i>Stenus</i> sp.		1			1	2	1	1		
<i>Lathrobium rufipenne</i> Gyll.									1	
<i>Lathrobium terminatum</i> Grav.		1	1		3	4	2	2	1	1
<i>Lathrobium</i> (s.l.) spp.					1	3	2		2	1
<i>Cryptobium fracticorne</i> (Payk.)		1		1	1	3	3	4		
<i>Gabrius</i> sp.			1	1	1				2	
<i>Gabrius</i> spp.								2		
<i>Quedius</i> sp.		1			1		3			1
<i>Quedius</i> spp.						2		2		
<i>Mycetoporus</i> sp.							1			
Pselaphidae										
<i>Bryaxis bulbifer</i> (Reich.)					1			2	2	1
Elateridae										
Elateridae indet.				1						
<i>Ampedus nigrinus</i> (Hbst.)				1						
<i>Denticollis linearis</i> (L.)										1
Coccinellidae										
<i>Coccinella</i> sp.					2	1	1	1		
Chrysomelidae										
<i>Plateumaris discolor/sericea</i> (Panz.)/(L.)			1							
<i>Cryptocephalus labiatus</i> (L.)						1				
<i>Phratora vulgatissima</i> (L.)					1					1
<i>Altica</i> sp.					5	2	1			1
<i>Chaetocnema hortensis</i> (Geoff.)				1						
Scolytidae										
<i>Hylurgops palliatus</i> (Gyll.)		1								
<i>Pityophthorus lichtensteini</i> (Ratz.)		2								
<i>Pityogenes bidentatus</i> (Hbst.)		1							1	
Curculionidae										

Curculionidae indet.					1			
<i>Deporaus betulae</i> (L.)								1
<i>Otiorhynchus nodosus</i> (Müll.)		20	2	2		2	1	2
<i>Phyllobius</i> sp.					1			1
<i>Strophosoma capitatum</i> (Deg.)			1		1	1		
<i>Rhyncolus ater</i> (L.)	1			1				1
<i>Anthonomus phyllocola</i> (Hbst.)			1		1			

**Table 11.2** Gammelhemmet Faunal list.

## 12 Gammplatsen, Lycksele

### 12.1 Site Description

Gammplatsen is located on a low lying, small headland in the Umeälven. The town of Lycksele lies directly to the south. The headland is just over 1km in length and approximately 350 m at the widest point. The elevation in the northern part is 211 m, gradually increasing to 224 m where the islet joins the mainland in the south, with a slight southeast to northwest tilt (Figure 12.1).

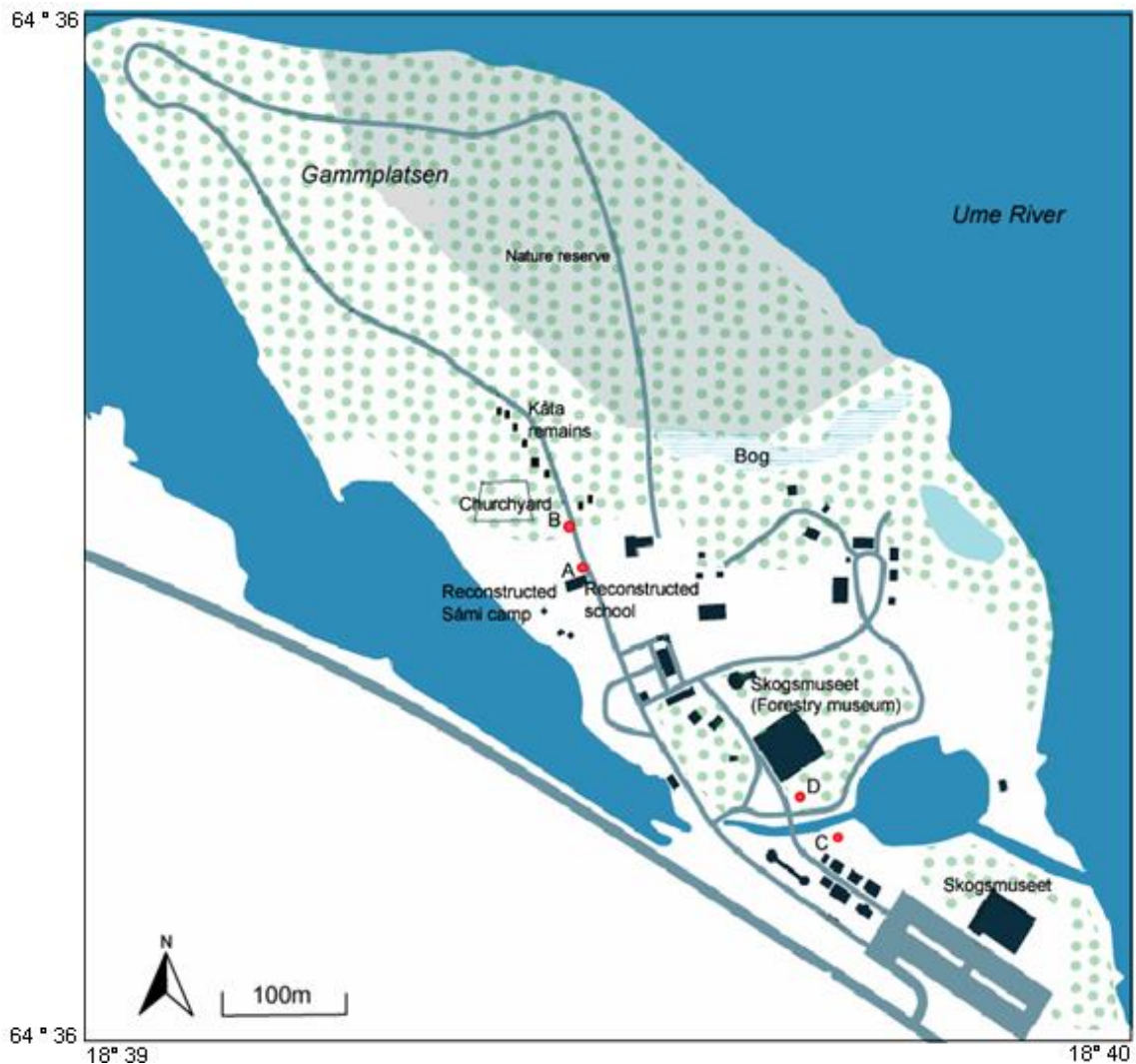
The site of Gammplatsen is situated within Lycksele Municipality, Västerbotten. The Umeälven, Vindelälven and Oreälven constitute the main river systems running through the area. Productive forest covers much of the area around Lycksele, exploited for forestry, reindeer herding and recreational activities (Nordström *et al.* 2010). The topography of the area consists of hills up to 250 metres in height. Pine-dominated mixed-coniferous forest, with *Vaccinium vitis-idea*, *Calluna vulgaris*, *Vaccinium myrtillus* and lichens, is extensive. *Betula*, *Populus* and *Alnus incana* occur to varying degrees within the region.

The northern part of the headland is most densely forested, with seven hectares of old pine and birch woodland, today a nature reserve. The forest floor is host to ericaceous shrubs including *Vaccinium vitis-idaea*, mat-grasses, mosses and lichens. The southern part of the headland consists of scattered woodland and areas of large clearances where reconstructed settlement remains and two museums now stand. Two small lakes are present and an abandoned river channel, now a bog dominated by grasses and sedges with some encroaching birch, is located in the central area (Figure 12.1).

The continental climate sees mean January temperatures of -11 to -13°C and mean July temperatures of 13-15°C with the first autumn frosts occurring at the beginning of September and the last frost at the start of June. The length of the growing season in the area is 140-150 days (Alexandersson and Eggertsson Karlström 2001).

## **12.2 *Cultural history***

The islet was designated as a historic site in 1948, to be managed by Lycksele Hembygdsigille (Lycksele Historical Guild). Gammplatsen, meaning ‘Old Site’, refers to its status as the original location of Lycksele church town before being moved to the current location. Many old buildings from across the Lycksele parish were moved to this new location, becoming part of the reconstructed church town, now a popular visitor attraction. The Skogsmuseet (Forestry Museum) buildings are in the southern part of the site, alongside the many reconstructed buildings.



**Figure 12.1** Map of Gammlplatsen the ‘Old Site’ showing the natural and cultural landscape of the islet and the location of the samples.

In the central area can be found the old churchyard, a reconstructed school building, a reconstructed Sámi camp (Figure 12.2) and some modelling scenes of life on the islet. An area to the north, 7 hectares in size, is now a designated nature reserve.



**Figure 12.2** Reconstructed kåta hut and pole store at Gammplatsen. Photograph by the author.

The site of Gammplatsen has a rich cultural history, documented through both the literary and archaeological record. The site is thought to have long hosted a Sámi winter village. Several hollows where Sámi kåta (huts) once stood are visible on the islet today and a radiocarbon date of  $1270 \pm 80$  AD from a piece of charcoal from a hearth supports the assertion of earlier use of the site (Rydström 2009).

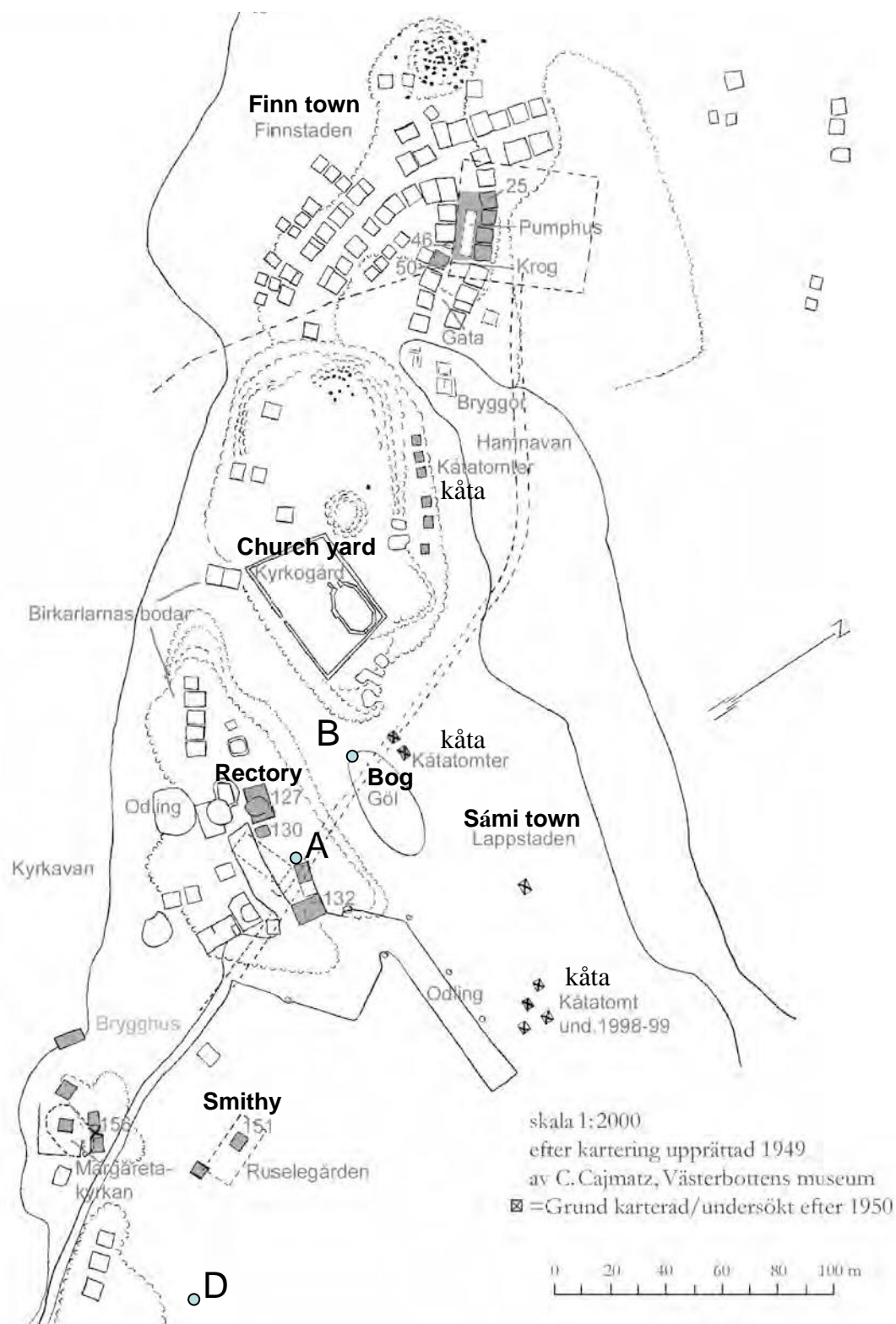
The church was built in 1606-07 AD, the first in Lapland (Huggert 2000). Despite attempts by the Crown to increase colonisation of the area, settlement was slow and numbers of residents remained small, with only a few families staying permanently on site. In 1632 AD a school was built, and many huts erected in association with winter tax collection and trade (Huggert 2000). In the mid-18<sup>th</sup> century settlers established themselves in the parish on a more permanent basis (Söderholm 1973).

The Sámi came to the market place sites for a short period of time each year before resuming their movements between winter habitats in the forests (Bergling 1964). Like the church and market places sites which succeeded them, Sámi winter villages were the places in which many important legal and economic issues were considered. Trading took place, taxes were collected, and decisions affecting the Sijdda groups would be decided (Bergling 1964; Carpelan and Hicks 1995).

Many excavations have been carried out on the site since the 1950s and the building remains and finds discovered have allowed the site to be divided into areas used by different groups of people. To the north of the churchyard, hearths and kâta pits identify the main area of Sámi occupation (Rydström 2009). Finds from this area date back to the 1600s. To the south of the churchyard additional clusters of kâta dwelling remains are present. In the northern part of the islet was the area where settlers set up their huts and cottages. The building foundations south of the churchyard have yielded a range of finds, including various kinds of glass, pottery and pipes. This is where the rectory once stood and the surrounding buildings are probably related to the rectory (Rydström 2009).

As the site became increasingly built up, the hazard of fire was recognised (Söderholm 1973). The county council records document a fire in 1695 AD which ravaged the school house. This was rebuilt on the mainland area, where the rest of the town would eventually be relocated. Later, in 1758 AD another more severe fire started in the rectory, destroying it and the surrounding buildings.





**Figure 12.3** Location of samples on map of the Old Site at Gammlplatsen (Column C taken outwith this area). Photograph by the author.



### **12.3 Sampling and Soil Profiles**

Several ditches dug across the site in connection with pipe laying work offered the opportunity to sample from various areas. From a ditch running 200m from outside of the reconstructed school building and north through the present-day woodland, one column of samples (Column A) and one bulk sample (Sample B) were obtained. Two further columns were taken, one from an open ditch between the car park and the small stream in the south (Column C) and another from a ditch opened at the side of the museum building (Column D) (Figure 12.1).

On the map of the old town (Figure 12.3) the sampling point of Column A is situated near the old rectory and two associated buildings thought to have burned down in 1758 AD. Three samples were taken, from 28-41cm (Figure 12.4). The lowest sample, from the irregular charcoal horizon, was restricted to 1 litre in size in an attempt to isolate the charcoal horizon. The remaining samples were 4 litres in size. The ground above and to either side of the samples was heavily disturbed.

A single bulk sample was taken from a peat inclusion (Figure 12.5) noted in the face of the same ditch, approximately 50 metres north of the Column A samples. This was restricted to 1 litre, the entirety of the small peat inclusion. This area of the site remains mostly wooded, with a mixed forest with old pine and birch and a forest floor dominated by mosses and grasses, as discussed above. The remains of kâta dwellings can be seen in the surrounding woodland as shallow depressions in the ground (Figure 12.6)

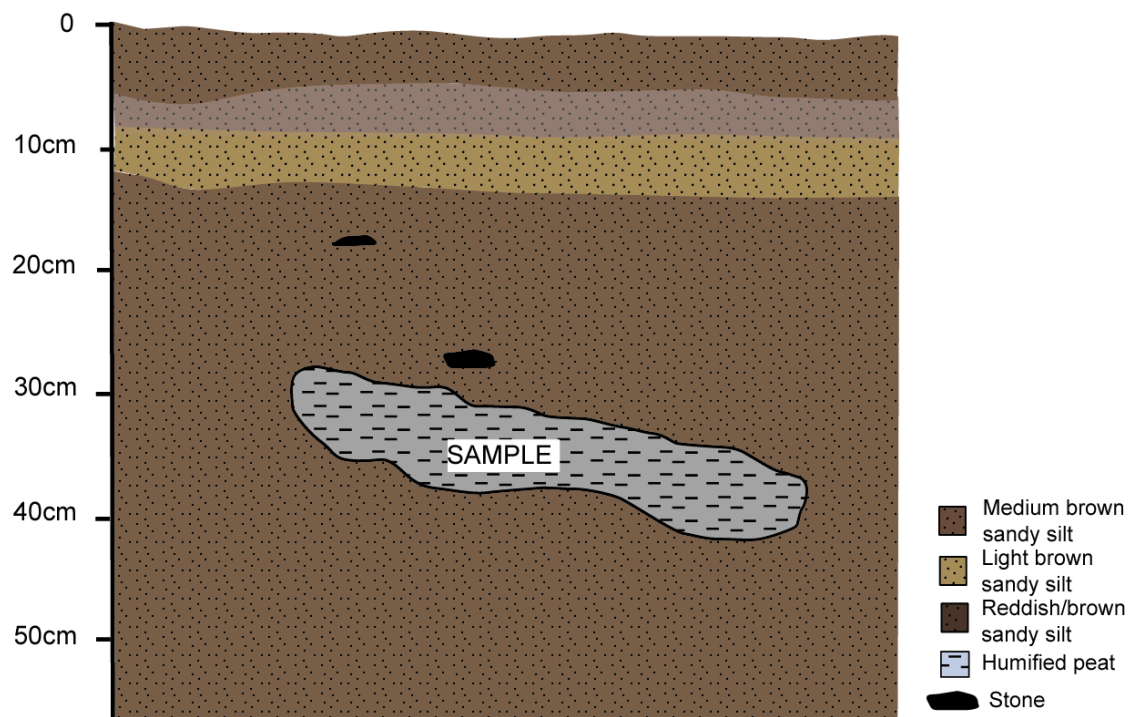


*Sample 1* (28-36cm): Dark brown/black sandy clay with charcoal inclusions to 1cm. Fragments of decorated clay pipes (Figure 12.9), pottery fragments and fire-cracked stones. Seeds of *Rubus idaeas* L., over 100 in number, and a few seeds of *Carex* sp. and *Comarum palustre* L. Hundreds of spores of *Cenococcum* fungi. Three fragments of bone up to 1.5cm were found. Abundant unburnt wood fragments. Less charcoal than in Sample 2.

*Sample 2* (36-39cm) Dark brown sandy clay silt with fragments of charcoal to 2cm. Fragments of green glaze pottery. Over 150 *Rubus idaeas* seeds, 50+ seeds of *Chenopodium* cf. *album* (L.) and hundreds of sclerotia of *Cenococcum* fungi. Eight fragments of bone reaching 3cm in length were found. Some inclusions of unburnt wood fragments.

*Sample 3* (39-41cm) Distinctive, irregular charcoal horizon measuring several centimetres thick in places. Charcoal pieces reached over 2cm in size. Some unburnt woody fragments.

**Figure 12.4** Soil profile and description of Column A, Gammlatsen. Photograph by the author.



**Figure 12.5** Soil profile showing context of Sample B at Gammlatsen.



**Figure 12.6** Kåta dwelling remains at Gammlatsen. Photograph by Eva Panagiotakopulu.

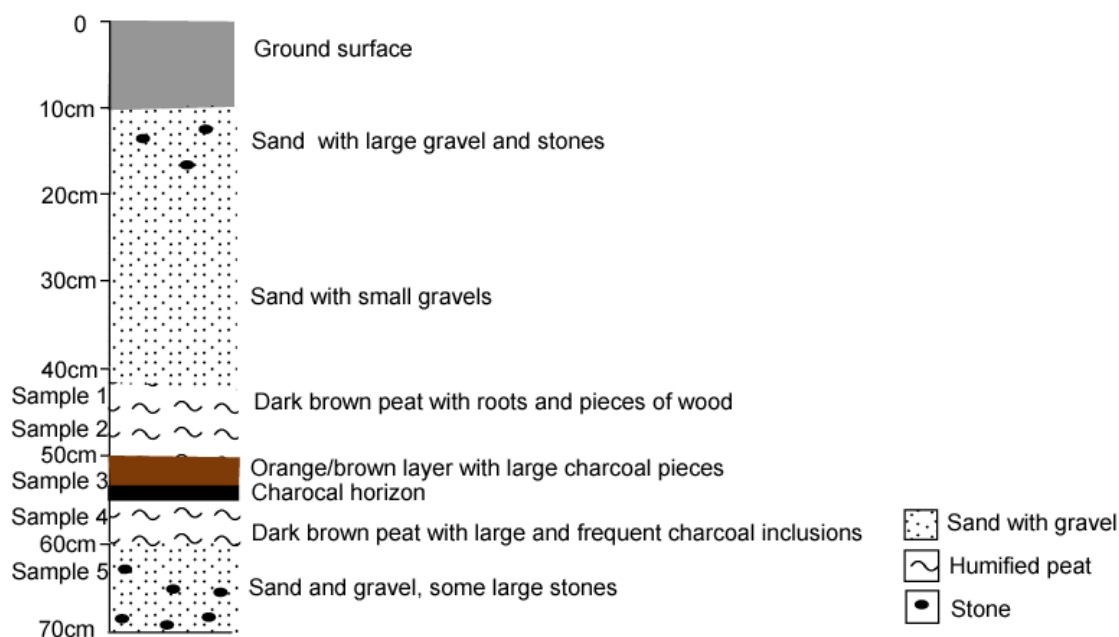


Column C was taken from an open ditch positioned between the car park and the small stream in the south of the area. Samples were taken in 5cm increments from 0-15cm and were 2 litres in size. All samples consisted of dark brown, silty clay. Inclusions of gravel were abundant in the basal sample, decreasing in abundance towards the top of the section.

Column D was taken from a ditch opened at the side of the museum building in 2008 (Figure 12.7). Sampling began at a depth of 40cm below the surface, where peat was evident and preservation conditions appeared favourable (Figure 12.8). Samples were then taken in 5cm intervals to a depth of 65cm and were approximately 3 litres in size.



Figure 12.7 Location of column D samples at Gammplatsen, looking northwest. Photograph by Eva Panagiotakopulu.



**Figure 12.8** Soil profile of Column D at Gammplatsen.

## 12.4 Preservation

Preservation varied greatly across the site. Despite the preservation of frequent inclusions of charcoal, wood fragments and seeds, preservation proved unsuitable for insect remains in Column A. The peat inclusion from the same ditch recovered remains in a condition that enabled identification to species level, however the remains were extremely fragile and some were fragmented. From Column C only a few remains were recovered, indicating the availability of certain habitats. Sand, gravel and stones in the lowest sample proved an unsuitable preservation environment, resulting in an absence of insect fossil remains in Column D. The preservation in Sample 4 (55-60cm) in Column D was fair, but several specimens were corroded and fragmented. Preservation in the remaining samples was good.

## 12.5 Dating

The open ditches around the site revealed a visible charcoal horizon running across much of the area. The opportunity to date the charcoal layer came primarily from Column A, where finds from above the charcoal horizon (Figure 12.9 and Figure 12.10) have been dated to the 18<sup>th</sup> century, determining that the charcoal layer and associated fire predate this period. Furthermore, two major fires are recorded in the county council record – one in 1695 AD started at the school and one in 1758 AD, which destroyed the rectory and surrounding buildings (Söderholm 1973). Using this information the charcoal horizon can be dated to between 1695-1758 AD, providing a dating framework for columns throughout the site. The only area in which this horizon was not noted is the peat inclusion (B).



**Figure 12.9** 18<sup>th</sup> century decorated clay pipe fragment from the Gammlatsen site. Photograph by Eva Panagiotakopulu.



**Figure 12.10** 18<sup>th</sup> century pottery from the Gammlatsen site. Photograph by Eva Panagiotakopulu.

## 12.6 Results and discussion

### 12.6.1 Landscape change

The dated charcoal horizon from Column A spans Samples 3 and 4 from Column D, dating these samples to the late 17<sup>th</sup>- mid-18<sup>th</sup> century and allowing the results to be discussed within the context of church town and market place activity at the site.

Sample 4 represents the landscape prior to the fire event. The prevalence of woodland species contrasts to the fauna found in samples strictly post-dating the fire. *Tomicus piniperda* (L.), a species of coniferous woodland, bores into the bark of weakened trees and suggests the presence of moribund timber (Lekander *et al.* 1977; Koch 1992). It appears to utilise standing trees rather than fallen dead wood. The shoots of pine trees play host to the species in breeding and maturation (Lekander *et al.* 1977). A specimen of *Corticaria* sp. is also noted from this sample. Many species of this genus are associated with the mould growing on decaying wood or from decaying vegetation, often in woodland environments (Koch 1989ab). *Pterostichus strenuus* is mostly known from the mosses and leaf litter of damp deciduous woodland and less commonly from grassland localities (Lindroth 1945; Harde 1984; Eyre and Luff 1990). It appears that shade is a necessary component of the preferred habitat of this species (Lindroth 1945).

Hygrophilous wetland staphylinids *Olophrum consimile* and *Stenus* spp. are present. *O. consimile* is found roaming the leaf litter of deciduous woodland, in the rich vegetation in bogs, meadows and around the edges of larger water bodies, often amongst *Carex* and mosses (Campbell 1983; Böcher 1995). The small pselaphid *Bryaxis bulbifer* is prevalent in very wet localities, inhabiting the mosses and vegetation detritus in marshes and damp woodlands (Koch 1989ab; Lott 2003).

In contrast, there appears to be an expansion of open areas in the surroundings during the phase covered by Sample 3. This sample has the highest number of large charcoal fragments. The staphylinids which appear during this phase are more accustomed to

open areas in meadows and bogs than to woodland localities. The Carabid beetles present may represent the development or expansion of damp bog or meadow, with drier areas of land constituting part of the landscape. Many of the eurytopic species present, including *Eucnecosum* cf. *brachypterum* and *Otiorhynchus nodosus*, could have exploited expanding grassland communities. High numbers of *O. nodosus* are present in this sample. This polyphagous curculionid feeds on a range of plants and is known from various environments including bogs, meadows and light woodlands (Koch 1989ab). Regardless of specific food preferences or host species of plant, it appears connected with open ground, and where found in wooded environments, it is within shrubby and patchy stands (Koch 1989ab). Lindroth and others (1973) record it primarily from meadow and grassland in Iceland. In the context of this assemblage *Otiorhynchus nodosus* may represent the development of meadow or heathland. *Eusphalerum luteum* is usually found in open areas of woodland where it resides amongst flowering herbs, particularly umbellifers, as well as shrubs and trees (Atty 1983; Koch 1989a). *Patrobis assimilis* is found only in Sample 3, again able to colonise a wealth of environments from open dry heaths and grasslands to damp shaded forests (Mani 1968; Lindroth 1985; Luff 1998). *Calathus melanocephalus* appears in the sequence, most commonly found from open and dry ground in meadows and grasslands (Lindroth 1974). Its presence has been frequently recorded in areas of arable land (Harde 1984; Koch 1989a; Duff 1993). The fauna clearly demonstrate opening up of the forest.

Aquatic beetles *Hydroporus* and *Helophorus* suggests damp conditions and the formation of small water pools. *Dyschirius globosus* is a species known from wet, open localities, in meadows and bogs, amongst mosses and rotting vegetation debris (Koch 1989a; Lindroth 1974). The most common habitat of *Agonum fuliginosum* is the mosses and grasses in extremely wet bogs and in the flood debris of nearby water bodies (Koch 1989a; Duff 1993). It is known that the headland was frequently affected by flooding (Soderholm 1973). Column D was taken from an area currently less than 20 metres from a small stream and lake. These species may be connected to the boggy area of land that was affected by such flooding.



The woodland remains well represented and dead and moribund trees continued to support the scolytids. Species tied to woodland include *Tomicus minor* samples. Similarly to *T. piniperda*, found in the previous sample, it attacks damaged, standing coniferous trees, although it exploits shoots higher up in the trees, as opposed to the lower trunk preferred by *T. piniperda* (Lekander *et al.* 1977). *Rhyncolus ater*, a polyphagous weevil occurring in the rotting wood of both deciduous and coniferous trees (Koponen and Nuorteva; Palm 1959) is only present in Sample 3. It is found in tree stumps, old standing and fallen trunks and also in living, but weakened trees (Koponen and Nuorteva 1973; Koch 1992). The weevil *Anthonomus phyllocola* is mostly known from pine trees in woodlands and heaths, the larvae maturing in the catkins (Koch 1992). *Tachyerges stigma* (Germ.) feeds upon the deciduous taxa *Alnus*, *Betula*, *Corylus* and *Salix*, often in quite open conditions on the margins of rivers and woodland (Koch 1992). The coniferous component of the woodland appears to dominate, with the expansion of pine. This does not necessarily equate to more closed woodland conditions, but may represent sparse cover of pine trees in heathland communities. The assemblage reflects an increasingly mosaic landscape, with elements of old growth coniferous and deciduous forest existing alongside open clearings, with drier grassy areas. This may have been partly caused by the fire event, however intentional clearance for the increasing population may also have played a role.

The mosaic forest structure is similarly represented in the fauna from Sample 2. The coniferous woodland appears to diminish as the deciduous community expands, perhaps exploiting the expansion of open clearings. Three individuals of *Phyllobius maculicornis* can be considered, alongside *A. phyllocola* and *T. stigma*, as representative of the woodland. *P. maculicornis* is polyphagous on young deciduous trees often in light areas of woodland (Duff 1993; Palm 1996). Dead wood habitats are no longer represented. The staphylinid population declines somewhat, with only *E. brachypterum* and *Stenus* spp. remaining. The aquatic and many of the hygrophilous species from the previous sample are not represented here.

The carabid beetles *P. strenuus* and *C. melanocephalus* both reach a peak in this sample, suggesting the continuity of both damp woodland and dry grassland habitats. It appears the area is somewhat drier overall, with few hygrophilous species. Fire may have been a frequent disturbance in the landscape, indicated by the presence of charcoal in these samples. A heath or meadow-like habitat, perhaps with isolated trees in and around it, is indicated.

The clearing of woodland in Sample 1 is evident in the disappearing woodland fauna, which is represented by only two species, *A. phyllocola* and *T. stigma*, which can be found in relatively open woodland habitats (Koch 1992). Of interest is the appearance of *Clivina fossor* (L.) a species found in open, moist ground, often amongst cultivated, vegetated soils and dense grasses (Lindroth 1985; Koch 1989a Duff 1993). Alongside *C. melanocephalus*, the indication is of the presence of grassland communities, possibly agricultural or pasture land.

It appears that the vegetation cover of the landscape became increasingly mosaic with the loss of old, mature woodland in the immediate locality at the expense of increasing open land. The development of deciduous trees within the forest could signify lighter and more open conditions as they pioneered in cleared areas of land. The overall indication is that the woodland was not closed and undisturbed, but was exploited, probably as a valuable resource for fuel and for building materials, as well as being cleared for arable or pasture land. It is not clear whether the upper samples date to the period of later expansion and intense occupation of the site in the 18<sup>th</sup> to early 19<sup>th</sup> century, or are post-19<sup>th</sup> century abandonment. The area in the south of the headland where the sample was taken was used for pasture after movement of the site to its new location and the fauna may reflect this more recent change in land use.

Charcoal was prevalent in the basal sample of Column C, allowing the profile to be dated to post 1695 AD, and therefore roughly analogous in time to the Sample 3 fauna

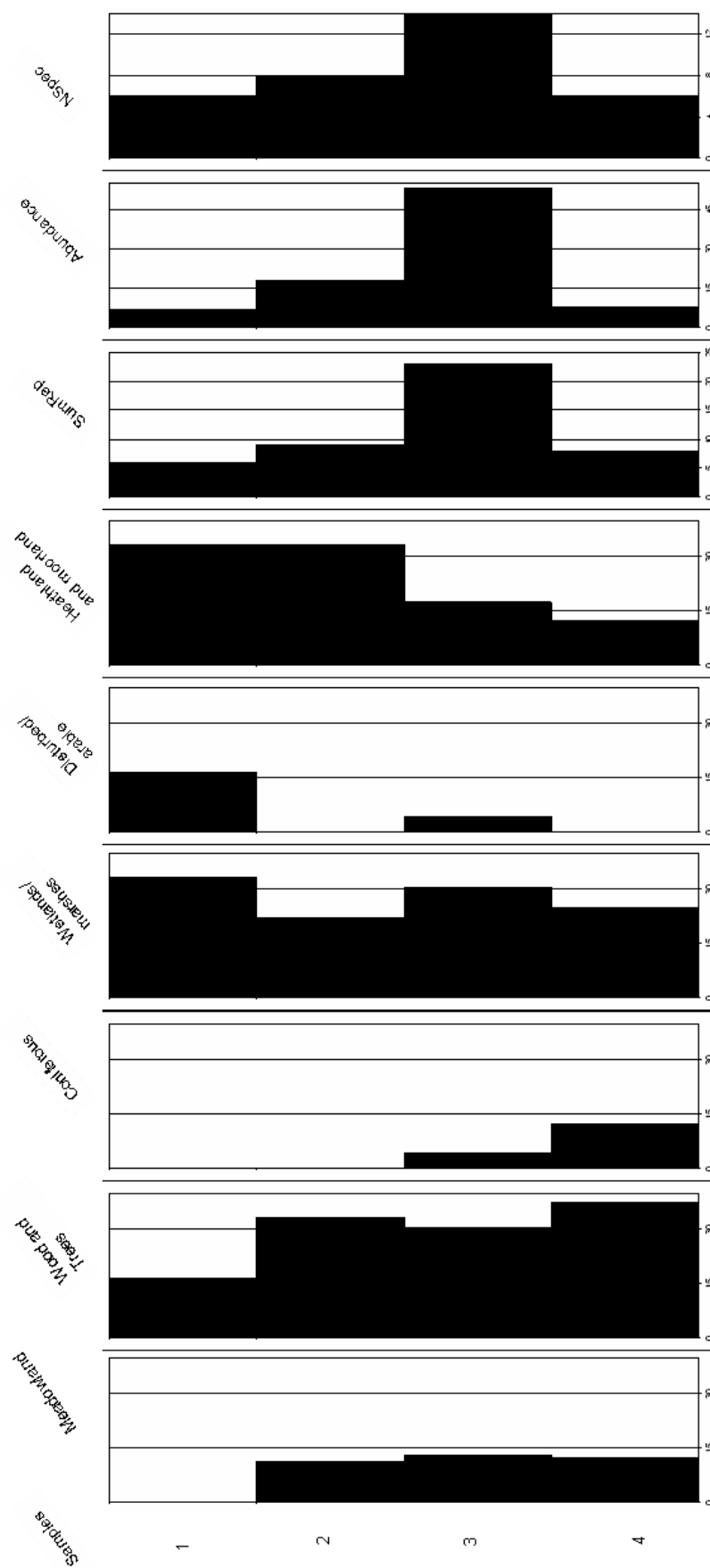
from Column D. This sample similarly held specimens of the curculionid *O. nodosus* alongside *E. brachypterum*, species found in damp bogs, meadows and woodlands amongst the vegetation litter, mosses, shrubs and grasses (Brundin 1934; Campbell 1984; Koch 1989a). Two individuals of the bark beetle family Scolytidae were also recovered. The very poorly preserved and fragmented elytra enabled identification to family level only. The presence of trees or wood are necessary for the breeding and development of many of the scolytid species, with many having a preference for moribund wood, suggesting that such a resource was available. *Hydroporus* sp. indicates an aquatic element in the surrounding landscape. A single individual of *Rhyncolus* sp. from the top sample (0-5cm) is testament to the surrounding woodland. Many of species of *Rhyncolus* attack the decaying wood of old trees and tree stumps (Koch 1992). Only *R. ater* and *R. sculpturatus* exist in the area today, both species are polyphagous on rotting wood of both coniferous and deciduous trees (Koch 1992). Although it is not exactly clear how the upper samples of Columns C and D relate in time, there may be a suggestion that whereas some areas were becoming increasingly cleared and converted to pasture land as interpreted from the Column D fauna, other areas remained more wooded, as seen in Column C.

The single bulk sample (B) cannot be dated securely in the absence of the dateable charcoal layer, however small charcoal fragments were prevalent (Table 12.1), suggesting that the sample originates from a fire affected landscape. The fauna recovered include those found in the assemblages described in the immediate post-fire samples of Column C and D, discussed above. Individuals recovered are eurytopic species typical of a range of damp moss and grass dominated environments. *Dyschirius globosus* is found primarily in damp, open environments where it resides amongst vegetation in meadows and mires and occasionally from sparse woodland (Koch 1989a; Fedorenko 1997). It is also found in flood refuse (Koch 1989a). *Acidota crenata* and *Eucnecosum* cf. *brachypterum* dwell amongst mosses and leaf detritus in bogs, meadows and damp woodlands. *A. crenata* appears to enjoy the shade provided by trees and shrubs (Brundin 1934; Larsson and Gíjja 1959; Campbell 1982). *Otiorhynchus nodosus*

is also present in this sample. The identified remains reflect a sparsely forested or shrub covered bog habitat in which drier hummocks and damp mosses and detritus provided suitable habitats.

Sample	300mm+	200mm+	50-150mm	4mm- 50mm	Less than 4mm
<b>Column A</b>					
1. 28-36	0	0	50	<100	<100
2. 36-39	0	25	<100	<100	<100
3. 39-41	0	5	<300	<200	<100
<b>Sample (B)</b>	0	0	0	<100	<300
<b>Column D</b>					
1. 40-45	0	0	0	20	30
2. 45-50	0	0	10	>100	>100
3. 50-55	0	0	<100	<100	<100
4. 55-60	0	0	30	<100	<30
<b>Column C</b>					
1. 0-5	0	0	0	0	0
2. 5-10	1	0	0	0	5
3. 10-15	13	20	40	<100	>100

**Table 12.1** Size and frequency of charcoal in samples from the Gammplatsen site.



**Figure 12.11** BugsEcofig.:. Diagram showing the presence of species in certain habitat groups at Gammplatsen Column D.

Sample 1: 40-45cm

Sample 2: 45-50cm

Sample 3: 50-55cm

Sample 4: 55-60cm.

### 12.6.2 Human activity

*Rubus idaeus* (Raspberry) seeds were found in high number in both Samples 1 and 2 from Column A, outside of the old rectory. This shrub tends to grow in light woodland, heathland, and on waste ground (Preston *et al.* 2002). *Chenopodium album* is common in disturbed ground which is rich in nutrients, and is also a weed of arable land (Blamey and Grey-Wilson 2003). It is also found in Sample 2.

It is possible that these reflect the growth of such plants in the nutrient rich, disturbed ground after a fire event. However, the context from which they were taken may suggest otherwise. Included alongside the seeds were abundant fragments of clay pipes, pottery, bone and fire cracked stones. Together, this assemblage is suggestive of a midden, with the seeds found being a product of consumption, entering the midden as waste. Indeed *Rubus idaeus* is a consumable fruit and in the past *Chenopodium album* has been cultivated (Kroll 1990; Stokes and Rowley-Conwy 2002).



**Figure 12.12** *Rubus idaeus* seeds from Column A at Gammlatsen.

At Bessastaðir, Iceland, preservation in an excavated midden enabled the identification of animal bones, seeds, insect and plant remains, and suggests that this Early Medieval deposit accumulated from the deposition of waste from inside of the longhouse (Sveinbjarnardóttir *et al.* 2007). At Sandoy, Faroe Islands, high numbers of synanthropic beetles have been found amongst deposits of charcoal, shells, fire-cracked stones, animal bone and seeds, and again demonstrates that material from inside the house was regularly dumped onto the midden outside (Church *et al.* 2005; Vickers 2006). Oats and barley were the principal seeds identified from the early medieval deposits in Iceland and the Faroe Islands.

The material from Gammplatsen, Lycksele, is the first investigated palaeocological material from a potential midden during the Post Medieval period in northern Sweden. It was located within the precinct of the old Rectory and its associated buildings (Figure 12.3). Buildings 127 and 132 have both been excavated, including finds of broken glass, pottery, porcelain fragments, 17<sup>th</sup> and 18<sup>th</sup> century pipe fragments and a bronze necklace (Rydström 2009). The palaeocological evidence from Column A suggests that there was an area where waste was deposited between the two main buildings associated with the Rectory.

The lack of insect fossil remains limits the ability to more fully establish the origins of and the conditions within the midden deposit, as has been done in the previously mentioned studies. This may also have given further insight into the conditions inside of the house, should the midden have included floor deposits. Nonetheless, an additional glimpse into the lives of the Lycksele inhabitants is given from these deposits, suggesting the consumption of certain foodstuffs, and also the division of space within the settlement.

That the rectory buildings were in use during the 17<sup>th</sup> and 18<sup>th</sup> centuries is evident from the dateable artefacts found. This may lend support to the possibility that the fire evident

in the charcoal layer is the fire of 1695 AD, and that the midden deposits are an accumulation from occupation after this date.

Fires have been a frequent occurrence on the islet. Overall, the size and abundance of large charcoal pieces in the Lycksele samples, reaching several centimetres in size, suggests that the area from which the samples originate was itself burned in a fire (Ohlson and Tryterud 2000; Gardner and Whitlock 2001). The risk of fire on the overcrowded islet was a cause of some concern (Rydström 2009), and two fires of anthropogenic origin are known to have occurred (Söderholm 1973). A smithy is located only 60 metres from the sampling location of Column D (Figure 12.3), its date of use unknown. It is possible that the surrounding area would have been used to provide necessary materials in the production of metalwork – mainly wood for fuel, or managed for charcoal production, important fuel in the iron making process (Emanuelsson and Segerström 2002), and intentionally burned for such purposes. Together, the historical evidence, and palaeoecological evidence of intense human disturbance, suggests that fires on the islet over the time period studied were primarily anthropogenic in origin.

No samples extending beyond the last few hundred years have been studied. However, that woodland still existed in the southern part of the headland around the time of church town establishment, as demonstrated in the lower samples of Column D, indicates that previous use of the site by the Sámi did not significantly affect the survival of this area of woodland. It is only in the last few hundred years that human impact has caused more drastic changes in the landscape.



<b>Sample</b>	<b>S1</b>	<b>S2</b>	<b>S3</b>
<b>Sample depth (cm)</b>	<b>28-36</b>	<b>36-39</b>	<b>39-41</b>
Faunal list			
Rosaceae			
<i>Rubus idaeas</i>	100+	150+	
<i>Comarum palustre</i>	5		
Amaranthaceae			
<i>Chenopodium</i> cf. <i>album</i>		50+	
Cyperaceae			
<i>Carex</i>	6		

**Table 12.2** Species list (seeds) from Column A at Gammplatsen.

<b>Faunal list</b>	
Carabidae	
<i>Dyschirius globosus</i> (Hbst.)	2
Staphylinidae	
<i>Eucnecosum</i> cf. <i>brachypterum</i> (Grav.)	1
<i>Eucnecosum</i> sp.	1
<i>Acidota crenata</i> (F.)	1
Curculionidae	
<i>Otiorhynchus nodosus</i> (Müll.)	2

**Table 12.3** Faunal list from bulk peat sample (B) at Gammplatsen.

<b>Sample</b>	<b>Top</b>	<b>Middle</b>	<b>Basal</b>
<b>Sample depth (cm)</b>	<b>0-5</b>	<b>5-10</b>	<b>10-15</b>
Faunal list			
Dytiscidae			
<i>Hydroporus</i> sp.		1	
Staphylinidae			
<i>Eucnecosum</i> cf. <i>brachypterum</i> (Grav.)			2
Aleocharinae indet.			1
Scolytidae			
Scolytidae indet.		2	
Curculionidae			
<i>Otiorhynchus nodosus</i> (Müll.)			1
<i>Rhyncolus</i> sp.		1	

**Table 12.4** Faunal list from Column C at Gammplatsen.

Sample	S1	S2	S3	S4
Sample depth (cm)	40-45	45-50	50-55	55-60
Faunal list				
Carabidae				
<i>Clivina fossor</i> (L.)	1			
<i>Dyschirius globosus</i> (Hbst.)			1	
<i>Patrobus assimilis</i> Chaud.			3	
<i>Pterostichus strenuus</i> (Panz.)		6	1	2
<i>Calathus melanocephalus</i> (L.)	1	3	2	
<i>Agonum fuliginosum</i> (Panz.)			1	
Dytiscidae				
<i>Hydroporus</i> sp.	1		1	
Hydrophilidae				
<i>Helophorus</i> sp.			1	
Staphylinidae				
<i>Eusphalerum luteum</i> (Marshall)			1	
<i>Olophrum consimile</i> (Gyll.)	2		3	1
<i>Eucnecus</i> cf. <i>brachypterum</i> (Grav.)	1	2	9	
<i>Acidota crenata</i> (F.)			4	
<i>Stenus</i> spp.	1	3	8	3
<i>Lathrobium terminatum</i> Grav.		1	7	
<i>Mycetoporus</i> sp.			1	
Aleocharinae indet.	1	1	2	
Pselaphidae				
<i>Bryaxis bulbifer</i> (Reich.)				1
Scirtidae				
<i>Cyphon</i> sp.	1			
Latridiidae				
<i>Corticaria</i> sp.				1
Scolytidae				
<i>Tomicus minor</i> (Hartig)			2	
<i>Tomicus piniperda</i> (L.)				2
Curculionidae				
<i>Otiorhynchus nodosus</i> (Müll.)		1	13	1
<i>Phyllobius maculicornis</i> Germ.		3		
<i>Rhyncholus ater</i> (L.)				1
<i>Anthonomus phyllocola</i> (Hbst.)	1	1	5	
<i>Tachyerges stigma</i> (Germ.)	1	1	1	

**Table 12.5** Faunal list from Column D at Gammlatsen.

## 13 Arvidsjaur

### 13.1 Site description

The sampled site is situated in an area of peatland approximately 2km northwest of Arvidsjaur in Norrbotten county (N 65 ° 60, E 19 ° 13) at 378m asl. Approximately 100 metres to the northwest of the sampled bog is the lake *Kvarntjärnenen guordnájávrátje*, bordered by luxuriant grasses and rushes. Several small rivers run from the south of the lake through the sampled bog. The birch tree belt at the fringes of the lake gives way to a thicker coniferous forest stand, which forms most densely to the west of the lake.

Between the bog where the samples were taken and the lake to the northwest is a strip of light woodland, consisting of pine and spruce with a dense ground vegetation of *Calluna*, *Vaccinium* and *Eriphorum* spp. (Figure 13.1). The bog itself is scattered with small, natural water pools with *Cladonia* and *Sphagnum* mosses and *Menyanthes trifoliata*. The drying surface of the bog is dominated by *Calluna vulgaris* (L.) Hull, *Vaccinium vitis-idaea*, *Eriphorum* spp., and *Ledum* sp. On the raised hummocks stand clusters of pine and birch trees. A few pioneer younger trees and shrubs dot the bog surface, with *Betula nana* being the most prominent. A standing snag is present. The modern main road lies to the south, approximately 50 metres from the sample location.

A hilly landscape characterises the land to the southwest, while a flat land of marshes, lakes and streams occurs to the north. The large lake system comprising Västra Kikkejaure and Arvidsjaursjön dominates in the northeast. The shores of these lakes are littered with remains of settlements dated from the Stone Age to the Iron Age (Riksantikvarieämbetet 2012).

The coniferous forest of the wider area is dominated by *Pinus sylvestris* with stands of *Picea abies* and inclusions of deciduous *Betula* spp., with *Vaccinium* forming the prominent understory vegetation type. Forests with lichen dominated ground flora are

prevalent along the rivers (Sjörs 1965). These forests provide year-round habitat for Sámi reindeer herders (Aronsson 1991).



**Figure 13.1** Vegetation at the Arvidsjaur sample site looking northwest through the belt of trees, with the lake visible in the distance. Photograph by the author.

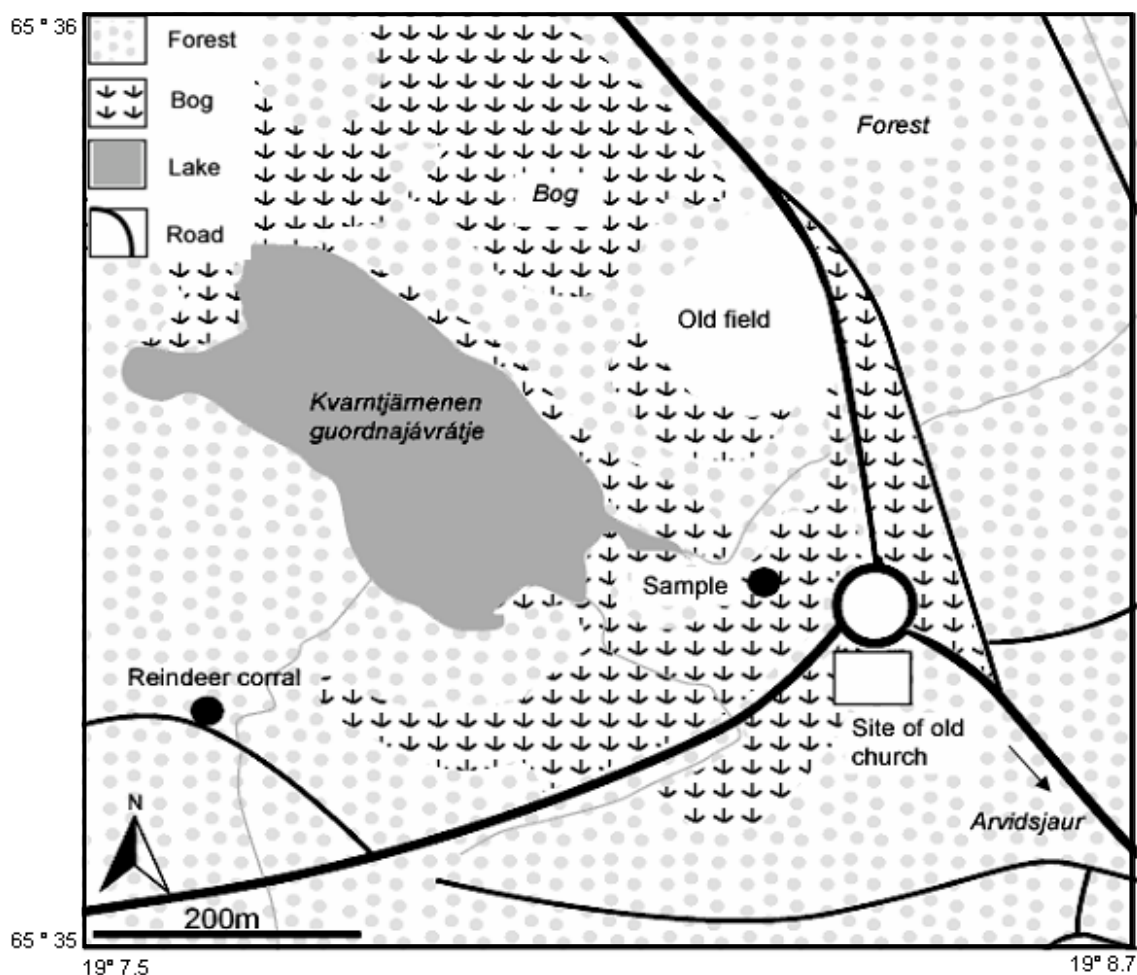
### **13.2 Cultural setting**

The church site of Arvidsjaur is one of the oldest in inland Norrbotten, officially established in 1606AD (Bergling 1964). Archaeological investigations have taken place in successive stages at the site since the 1960s. Extensive remains relating to past settlement, including building foundations, hearths, pipe fragments, glass, metalwork and a variety of mammalian bones, have been recorded. Most of the artefacts date to the 17<sup>th</sup> and 18<sup>th</sup> centuries (Liedgren 1997).

Little is known about the history of this site prior to its official establishment as a church and market place in 1606. The local dialect uses the term ‘Dalvedis’ for the site, a name

given to Sámi winter villages (Bergling 1964). Items connected to Sámi activity include an iron arrowhead and a silver ring. Reindeer bones dominate the osteological material from the site and the presence of all parts of the skeleton suggests they were butchered on the site (Liedgren 1997). Radiocarbon dates of charcoal from excavated hearths extend back to the late 12<sup>th</sup> century (Liedgren 1997).

The site of the 17<sup>th</sup> century church is situated approximately 400 metres south east of the sample site. A reindeer corral lies approximately 350m to the west, although there is no indication of its period of use (Riksantikvarieämbetet 2012).



**Figure 13.2** Sample location at Arvidsjaur.

### **13.3 Methodology**

A sampling pit was dug in the peat bog to a depth of 65cm. The upper 10cm of the modern surface layer was removed and then samples were taken at 5cm intervals, with a total of 13 samples. Each was approximately 5 litres in size. From the soil profile a marked change to less humified peat can be seen from around 25cm (Figure 13.3).

The insect fossil remains from the top 25cm were more poorly preserved than the rest of the sequence, with the recovery of some thin and pale elytra. In some instances only the elytra or thoraces of species were found, which were not diagnostic enough in themselves to permit identification to species level, for example for *Atomaria*, *Corticaria* and *Coccinella*. No charcoal was found in the samples.

### **13.4 Dating**

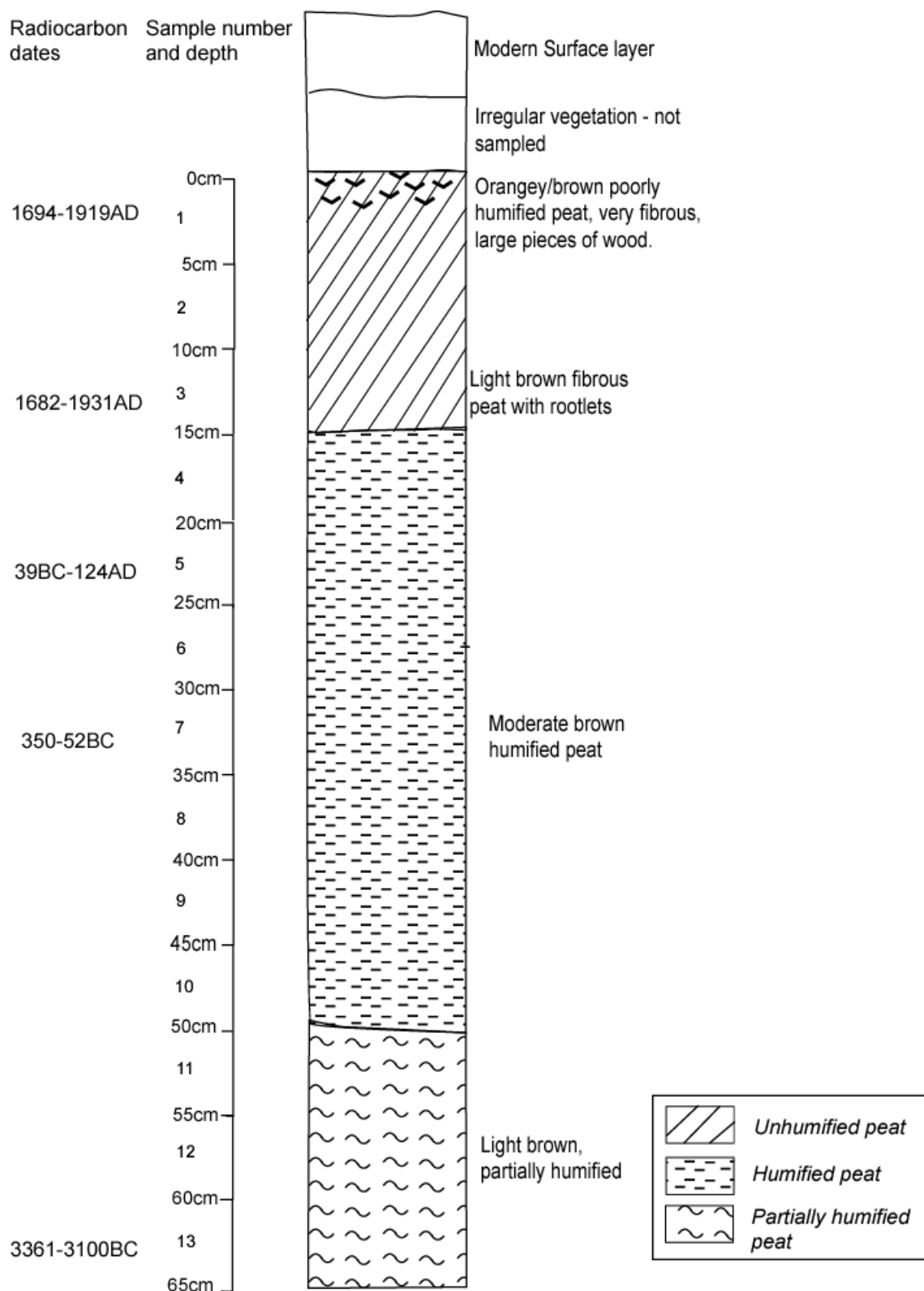
Material for radiocarbon dating was carefully recovered from five samples throughout the succession. A basal date was obtained to provide the start-point of the chronological succession, and a further four dates were taken from key samples to enable the environmental changes witnessed in the insect fossil record to be placed in their chronological context.

In order to avoid the dating inaccuracies often caused by contamination by rootlets and transported organic carbon when dating bulk samples and humic acid (Kilian *et al.* 1995; Shore *et al.* 1995; Nilsson *et al.* 2001), seeds were used for dating in the majority of samples as they have a short life span. With the exception of *Carex* spp., all of the seeds were able to be identified to species level.

Plant remains of *Sphagnum* section *Acutifolia* were used in the absence of suitable seeds. In their investigation of the accuracy of  $^{14}\text{C}$  dating of peat samples in Sweden, Nilsson and others (2001) found *Sphagnum* to be a reliable material for dating. These mosses

lack roots and therefore the incorporation of old carbon from lower layers is not considered a significant problem (Goslar *et al.* 2005).

The results demonstrate a straightforward chronological sequence through the sampled column over approximately the last 5000 years. From Sample 5 (20-25cm), a date of 39 BC – 124 AD was returned from *Menyanthes trifoliata* seeds, and from Sample 3 (10-15cm) a date of 1682-1931 AD was obtained from *Sphagnum*. The long time span covered over this short depth may be a result of the slow accumulation of peat, or possibly a gap in the succession as a result of peat cutting. This will be considered further within the discussion.



**Figure 13.3** Soil profile with dates from the site of Arvidsjaur.



Depth	Material dated	Uncalibrated date (BP)	Calibrated age with 95.4% probability (2σ)	Lab Code
0-5cm	Seeds: <i>Andromeda polifolia</i> L.	45±30	1694-1919AD	SUERC-33094 (GU-3309)
10-15m	Bryophyte: <i>Sphagnum</i> sect. <i>Acutifolia</i>	95 ± 30	1682-1931AD	SUERC-36757 (GU-25293)
20-25cm	Seeds: <i>Menyanthes trifoliata</i> L.	1955±30	39BC-124AD	SUERC-33483 (GU-3310)
30-35cm	Seeds: <i>Menyanthes trifoliata</i> L.	2130±30	350-52BC	SUERC-33098 (GU-3311)
60-65cm	Seeds: <i>Carex</i> spp.	4525±35	3361-3100BC	SUERC-33484 (GU-3312)

**Table 13.1** Radiocarbon dating results from Arvidsjaur.

### 13.5 Results

The samples are initially dominated by aquatic species. Water-dwelling beetles *Hydroporus* sp. and the large predacious diving beetles of the genus *Agabus* are found alongside *Coelostoma orbiculare* (F.), which lives in the vegetated margins of stagnant water pools in fens and bogs amongst mosses and organic matter (Merritt 2006; Foster 2009). Most species of *Dryops* found in northern Sweden are hygrophilous (Backlund 1945), and elsewhere are found in mossy waterside habitats and amongst vegetation detritus (Foster 2000). The water beetles *Enochrus* spp. often frequent fens, *Sphagnum* bogs and lake margins, seeking out the vegetative litter on which to feed (Foster 2000; Merritt 2006).

*Olophrum rotundicolle* (Sahl.) inhabits the grasses and mosses in bogs, the leaf litter of *Alnus* and *Salix*, and also the margins of lakes and streams (Campbell 1983; Böcher 1995). The hygrophilous beetles *Lathrobium terminatum* (Grav.) and *Stenus* sp. are also present in small numbers. *Pselaphus heisei* Hbst. dwells in riparian habitats, in fens and

bogs in reed litter, grassy tussocks and mossy carpets (Pearce 1957; Atty 1983). Elytra of *Catops* sp. were unidentifiable to species level. Members of this genus are known from damp habitats, in woodlands and floodplains, and also from disturbed dry land (Koch 1989a). Most of all they seem to be attracted to foul organic material, including carrion, mouldy vegetation and rotting wood (Donisthorpe 1939; Koch 1989a; Duff 1993).

*Pterostichus strenuus* (Panz.) is most commonly found roaming the ground vegetation in damp woodlands (Duff 1993), and Lindroth (1945) suggests that shade is a necessary component of the environment, whether by trees or tall herbs. It is similarly known from more open areas, in natural grasslands, fens and lake shores (Lindroth 1945; Eyre and Luff 1990). Species of *Altica* may be found in meadows and floodplains, also in the mossy carpets of bogs and in woodland margins, often feeding on heath plants and herbs (Bullock 1993; Duff 1993; Koch 1992). Exposed areas where rich grasslands flourish are preferred by *Ctenicera pectinicornis* (L.) (Hyman 1992). *Athous* sp. is n Sample 11, a species often found in open grassy areas and woodland clearings (Koch 1989ab).

From Sample 11 onwards *Acidota crenata* (F.) becomes a persistent part of the assemblage, a species known from a variety of woodland, meadow and bog habitats where it roams amongst damp leaf litter, mosses and grassy hummocks (Brundin 1934; Campbell 1982). *Staphylinus erythropterus* L. is found in the ground litter of *Salix* scrub, although is most abundant in the damp, grassy vegetation of fens and water margins (Koch 1989a; Duff 1993). *Lathrobium terminatum* and sporadic occurrences of *Lathrobium rufipenne* Gyll. are found throughout the sequence. Both are predatory amongst the damp vegetation in bogs (Brundin 1934; Duff 1993). Mosses and grasses in wet bog environments are preferable for *Philonthus nigrita* (Grav.) and *Cryptobium fracticorne* (Payk.) which first appear in the sequence from Sample 10. The hygrophilous *Olophrum consimile* (Gyll.) is often found in damp vegetation of mosses and vegetative litter in bogs, the edges of streams and lakes, and under small shrubs (Campbell 1983; Böcher 1995).

Tree-dependent species are low in Samples 9-13. In Sample 12 *Dorytomus* sp. indicates the presence of deciduous trees, many species of this genus preferring *Salix* and *Populus* in which the larvae develop in the catkins (Hyman 1992; Bullock 1993), while *Deporaus betulae* (L.) is present in Sample 10, a beetle dependent upon broadleaved trees in various stages of its life cycle. The larvae develop in leaf rolls, favouring *Betula*, *Alnus* and *Corylus* (Koponen and Nuorteva 1973).

The aquatic environment is represented by peaking numbers of *Hydroporus* cf. *melanarius* Sturm in Samples 5, 6, 7 and 8, a beetle primarily inhabiting small peaty water pools in woodland localities (Nilsson and Holmen 1995). *Hydroporus* cf. *umbrosus* (Gyll.) is added to the assemblage in Sample 7. This species is common in richly vegetated, still water bodies, particularly lakes and ponds (Nilsson and Holmen 1995). In Sample 8 *Berosus luridus* (L.) is also found, usually indicative of standing water where the mud of lake margins and at the base of shallow ponds is a suitable habitat for the larvae (Koch 1989a; Foster 2000). Alongside these aquatic beetles are raised numbers of *Plateumaris discolor* (Panz.) found in a range of waterside vegetation including *Carex* and *Eriphorum*, the larvae living at the roots (Stainforth 1944; Koch 1992; Flint 1963). *Donacia obscura* Gyll. is similarly found in aquatic habitats where it is recorded primarily from sedges and rushes in lake margins and fens (Hyman 1992). It is present at the site in Samples 5 and 6 only. *Rhantus exsoletus* (Forst.) also exploits the abundant vegetation around the water margins, and is often found in the vicinity of permanent lakes or streams (Nilsson and Holmen 1995; Merritt 2006).

From Sample 8 onwards *Otiorhynchus nodosus* (Müll.) becomes a persistent part of the assemblage. This weevil is well adapted to a number of different habitats, including wetlands, heaths and sparse woodlands (Brundin 1934; Koch 1992). *Rhagonycha testacea/limbata* (L.)/(Thoms.) is found in open areas in woodland, on flowering shrubs in woodland meadows, often in dry, sun exposed places (Koch 1989ab). *Chaetocnema concinna/picipes* Marsham/Stephens, could indicate grassland or riverside vegetation

(LeSage 1990; Koch 1992; Duff 1993), and occurs in Samples 7 and 8. In Samples 4-7 *Patrobis assimilis* Chaud. was recorded. It is known from a variety of habitats including vegetation detritus and *Sphagnum* polsters in bogs, open heaths and boggy woodlands (Lindroth 1985; Koch 1989a).

The small weevil *Micrelus ericae* (Gyll.) was found in Sample 6. Both adults and larvae feed upon *Calluna* and *Erica* spp. in heathlands. *Sericus brunneus* (L.), although sometimes found in coniferous woodland localities, depends on open grassy environments for larval development, and occurs mainly in heaths and woodland clearings and margins (Koch 1989ab; Laibner 2000). Also present in this sample is *Otiorhynchus ovatus* (L.), a flightless polyphagous weevil often found in areas with dry sandy soils (Duff 1993). A single occurrence of *Aphodius nemoralis* Er. in this sample indicates the presence of herbivore dung, often elk and deer droppings (Jessop 1986; Landin 1961). It appears to favour the shaded conditions of woodland (Landin 1961; Hyman 1992).

Sample 6 also contains the first indicators of rotting wood habitats. *Rhyncolus ater* (L.), which seeks out the rotting trunks and stumps of coniferous and deciduous wood (Koponen and Nuorteva 1973), appears at this time. The heavily rotten and decaying wood of old and dying coniferous trees are also favoured habitats of the click beetle *Ampedus nigrinus* (Hbst) (Horion 1953; Palm 1959; Koponen and Nuorteva 1973). The larvae are often recorded from beneath the bark where they develop (Koponen and Nuorteva 1973; Duff 1993). The mould itself may be an important substrate for these beetles (Hunter 1977; Koch 1989ab). Alongside beetles of old and dead wood occurs the deciduous tree feeder *Cryptocephalus labiatus* (L.), which appears to favour young trees in light woodland margins and heathlands (Lane 1992; Duff 1993). *Pityophthorus lichtensteinii* (Ratz.) is found particularly on pine, on the thin, dying or dead twigs and branches, often in light areas of woodland heaths and bogs (Lekander *et al.* 1977; Koch 1992). The pine feeding weevil *Anthonomus phyllocola* (Hbst.) is similarly found in light areas of pine woodland, in heath and bogs (Morris 1977; Koch 1992).

*Tomicus minor* (Hartig) is present in Samples 3 and 4, a species exploiting pine and spruce trees that are in a weakened state, usually in trees that remain standing, with new shoots important for the maturation phase (Lekander *et al.* 1977). Dead trees may also be exploited (Lekander *et al.* 1977; Winter and Evans 1990; Alexander 2002). Individuals of the genus *Corticaria* are often found in woodland environments where decaying vegetation, rotting wood and associated fungi provide favourable food substrates (Koch 1989ab). Some species have been recorded on burnt and cut stumps of trees (Palm 1959; Koch 1989ab). Others are more indicative of mouldy vegetation, on the woodland floor or fen margins (Koch 1989ab). Weedy places, meadows and pastures also host members of this genus (Koch 1989ab; Duff 1993). Others are now strictly synanthropic, exploiting hay-refuse, granaries and stables (Lindroth *et al.* 1973; Böcher 1988; Duff 1993). Unfortunately the retrieval of elytra alone made secure identification to species level impracticable in this easily confused group. Members of *Atomaria* inhabit a similar range of habitats, and a single elytron was found in Sample 4.

Two ladybirds of the ubiquitous genus *Coccinella* were recovered from Sample 4. Also from this sample is *Anthophagus alpinus* (Payk.), found in a range of meadow plants and in light areas where *Salix* and *Betula* has taken root (Brundin 1934; Koch 1989a). An individual of *Amara lunicollis* Schiödt was also recovered. In Scandinavia Lindroth (1986) notes this species from quite dry areas of ground, in open localities such as in *Calluna* heath and grasslands, and also in light woodland. *Tachyporus pusillus* Grav. has been recorded from mosses and grasslands in light woodlands, and also from drier grass and heathland areas, in crop fields, pastures and mouldy hay (Atty 1983; Koch 1989a; Duff 1993). The persistant deciduous woodland is documented by the tree species *C. labiatus* and *D. betulae*, along with woody-substrates indicated by *T. minor*. The most diverse range of hygrophilous staphylinids from the sequence are found here.

In Sample 3 only one individual of *Enochrus* is representative of this once abundant habitat group. This decline in aquatic beetles accompanies as overall fall in numbers of

recovered remains. *Eucnecosum* cf. *brachypterum* (Grav.), having entered the scene in Sample 5, accompanies a dwindling population of Staphylinids in Samples 2 and 3. It is an inhabitant of various damp environments and in northern Sweden is commonly found from grassy areas, in heaths, meadows and bogs (Brundin 1934; Bengtson 1981). Sample 3 retains indications of the wider woodland, with *T. minor*. Open heath species are found alongside wetland rove beetles *Stenus* sp. and *L. terminatum*.

In Samples 1 and 2 the recovered fauna is much reduced. Sample 2 is characterised by a few water dwelling species, including *H. umbrosus* and *Ochthebius minimus* (F.) alongside the bog species *P. discolor*. The appearance of *Leptura* sp., a genus found primarily in decayed wood in deciduous forests (Alexander 2002) alongside *Cryptocephalus* sp. in Sample 1 suggests the presence of trees in the vicinity with a limited hygrophilous fauna foraging in the ground layer.



**Figure 13.4** Recovered insect fossil remains from Sample 4 at Arvidsjaur. Photograph by the author.

### 13.6 Discussion

Initially, the site is dominated by aquatic species, including *Hydroporus* sp. and *R. exsoletus*. Many of the recorded beetles are found near lake margins, in vegetated fen communities. Similarly the Staphylinids present are found in association with freshwater habitats or pools in fens and bogs. Only a single individual of *Dorytomus* sp. indicates the presence of trees in the environment. The fauna represent a developing lake-side habitat at this time. The basal sample (Sample 13) held abundant *Carex* seeds, dated to 3361-3100 BC.

The fauna diversifies and scattered trees became established in the area from Sample 12. *D. betulae* indicates that deciduous species such as *Betula*, *Alnus* and *Salix* may have colonised the wet surface or fringes of the fen. *O. rotundicolle*, *A. crenata* and *S. erythropterus* sought out the damp leaf litter and mosses, possibly within establishing *Salix* scrub or *Alnus* carr woodland. The presence of *P. strenuus* indicates that the vegetative cover must have been sufficiently luxuriant to provide cover for this shade-dwelling species. *Chaetocnema concinna/picipes* found suitable conditions within the grassy tussocks.

A diversification of aquatic fauna and high number of hygrophilous species lived at the site from Sample 9. The aquatic beetles *H. melanarius*, *E. ochropterus* and *B. luridus* are all present for the first time, found in stagnant water pools in bogs and fens (Nilsson & Holmen 1995; Foster 2000) and hygrophilous Staphylinids such as *O. consimile*, *L. rufipenne* and *P. nigrita*, wetland inhabitants dwelling in vegetative litter, often in the vicinity of freshwater (Lindroth 1974; Campbell 1983; Lott 2003), all enter the assemblage. The assemblage indicates the expansion of a sparsely wooded, wet bog community.

Open and dry areas were accessible in the nearby surroundings, or raised hummocks within the bog, with *Athous* sp. dependent on this habitat for larval development. Such habitats continued to develop, and a mosaic landscape hosting species which inhabit a range of different ecological niches were recovered from Sample 6. Numbers of *Altica* sp. and *O. nodosus* are at their highest. These occur alongside *O. ovatus*, a species known from vegetation growing in sandy areas (Duff 1993; Morris 1997). *M. ericae* is commonly found on *Calluna* in heaths and bogs (Böcher 1995; Morris 2008) and *S. brunneus* may also have exploited the shrubs growing in and around the bog. *A. nemoralis* indicates the presence of grazing herbivores in the area (Landin 1961), whether of wild or domesticated animals is unknown.

The presence of *C. labiatus* suggests deciduous trees in and around the damp bog. The presence of tree-dependent *Rhyncolus ater* and *Ampedus nigrinus* is interesting within the context of this assemblage. *R. ater* is found in old, sometimes rotten wood, both of standing and fallen trees, usually coniferous species (Koponen and Nuorteva 1973). *A. nigrinus* is similarly found in old wood, in stumps and on logs (Koponen and Nuorteva 1973; Koch 1989ab). The indication of woodland in the assemblage is generally low, apart from these dead-wood species.

The assemblage as a whole, with inclusions of heath species and beetles found in relatively exposed areas, suggests that woodland cover was not extensive, during the Early Iron Age, and the fauna appear to reflect an open, wet, lakeside locality. The dead wood fauna could represent occurrences from the wider woodland, or could have originated from dead wood being brought onto the site for use as fuel or building material.

*Coelostoma orbiculare* (F.) is present until Sample 7 (350-52 BC), after which it disappears from the sequence. This species has a generally southerly distribution in Scandinavia today, and although it has been recorded from Västerbotten, it is absent from other localities in northern Sweden (Gustafsson 2005). It has a TMaxLo of 12°C (lower limit of reconstructed mean temperature of the warmest month). *Berosus luridus*



(L.) is also found in Sample 8 (<350 BC). This species has a TMaxLo of 13°C. That many of the other species that exploit similar habitats to *Coleostoma orbiculare* remain present in the sequence beyond this point could suggest that changes in temperature may have contributed to its disappearance, although there is not enough evidence to verify this with any degree of certainty. Declining temperatures have been reconstructed from c. 600 BC in the tree-ring data from Swedish Lapland, with a severe cold snap at 330 BC, during which summer temperatures may have plunged abruptly (Grudd *et al.* 2002).

The fauna from Sample 5 indicates that the surrounding environment remained wet, with stagnant water pools. Many of the Staphylinids that were previously found within the moss and vegetative litter are absent. Again, wood-dependent species are present, indicating the presence of living trees or disturbed woodland. The character of the assemblage is very open and indicates a lightly wooded heath surrounding the damp bog.

AMS dates from Sample 5 of 39 BC-124 AD and from Sample 3 of 1682-1931 AD give some guidance as to the date of the Sample 4 fauna. From the 1500s the site is thought to have been used seasonally by low numbers of people (Bergling 1964; Liedgren 1997), and there is evidence that the site was utilised as a Sámi winter village prior to this (Table 13.2). Hicks (1993) and Carpelan and Hicks (1995) recorded a decline in *Pinus* and presence of anthropogenic indicator species, at winter village sites in northern Finland, indicating the opening up of the forest in response to intermittent Sámi occupation.

Several species, including *A. alpinus*, *Amara lunicollis*, and *Coccinella* spp., are present in Sample 4. These species indicate the expansion of open areas, particularly *A. lunicollis*, which indicates the spread of open *Calluna* heath. *T. pusillus* may be considered as one of the opportune species exploiting the expanding open areas, being found in both wetland localities and also grassy heaths, although it flies readily. At the same time there was a decrease in aquatic fauna. The dead wood fauna, including *P.*

*lichtensteini* and *Tomicus minor*, may represent either the surrounding woodland, or dead wood being brought to the site. Pine was often used preferentially for fuel and for building material, as it dries out more readily than do other species (Hicks 1995).

A few specimens were notably pale and corroded in the upper three samples. There is a decline in the aquatic fauna recovered in Sample 3, the first time in which *Hydroporus* is absent from the sequence. Only a few wetland species remain. Remnants of the woodland fauna include a single specimen of *T. minor*. *Altica* sp. and *O. nodosus* persist in small numbers. *E. brachypterum* reaches a peak in this sample and the assemblage overall indicates a damp area of heath.

Sample 3 has been dated to 1682-1931 AD, incorporating the period of church and market place use. Evidence of hearths, pits, and wooden structures have been recorded in the area around which the sample was taken (Figure 13.5) (Liedgren 1997). The sampling point is located in the area deemed as the 'Primary settlement' area, where concentrated areas of elevated phosphate levels were recorded (Karlsson 2006) (Figure 13.6). Karlsson (2006) considers these areas of elevated phosphorous and organic matter to indicate areas of concentrated activity.

Between Samples 3 and 5, the dating evidence suggests that 15cm of peat accumulated in 1500 years (Figure 13.3). This could potentially be explained by slightly erroneous radiocarbon dates, and/or by a low sediment accumulation rate during this period, altered by hydrology, vegetation type, climate and nutrient and carbon cycles (Charman 2002). Higher numbers of individuals and slightly increased diversity of the insect fossil remains may have been expected in these samples should that be the case (Buckland 2007, 172). In Greenland, Schofield *et al.* (2008) found a hiatus in the soil profile which they suggest may be evidence of peat cutting in connection with Norse settlement at a farm (Ø34) in the Eastern Settlement. In northern Sweden settlers cut peat extensively (Hellström 1917), and the removal of peat layers could be a possible explanation for the apparent gap in the succession. Peat bogs have been important sources of fuel across the

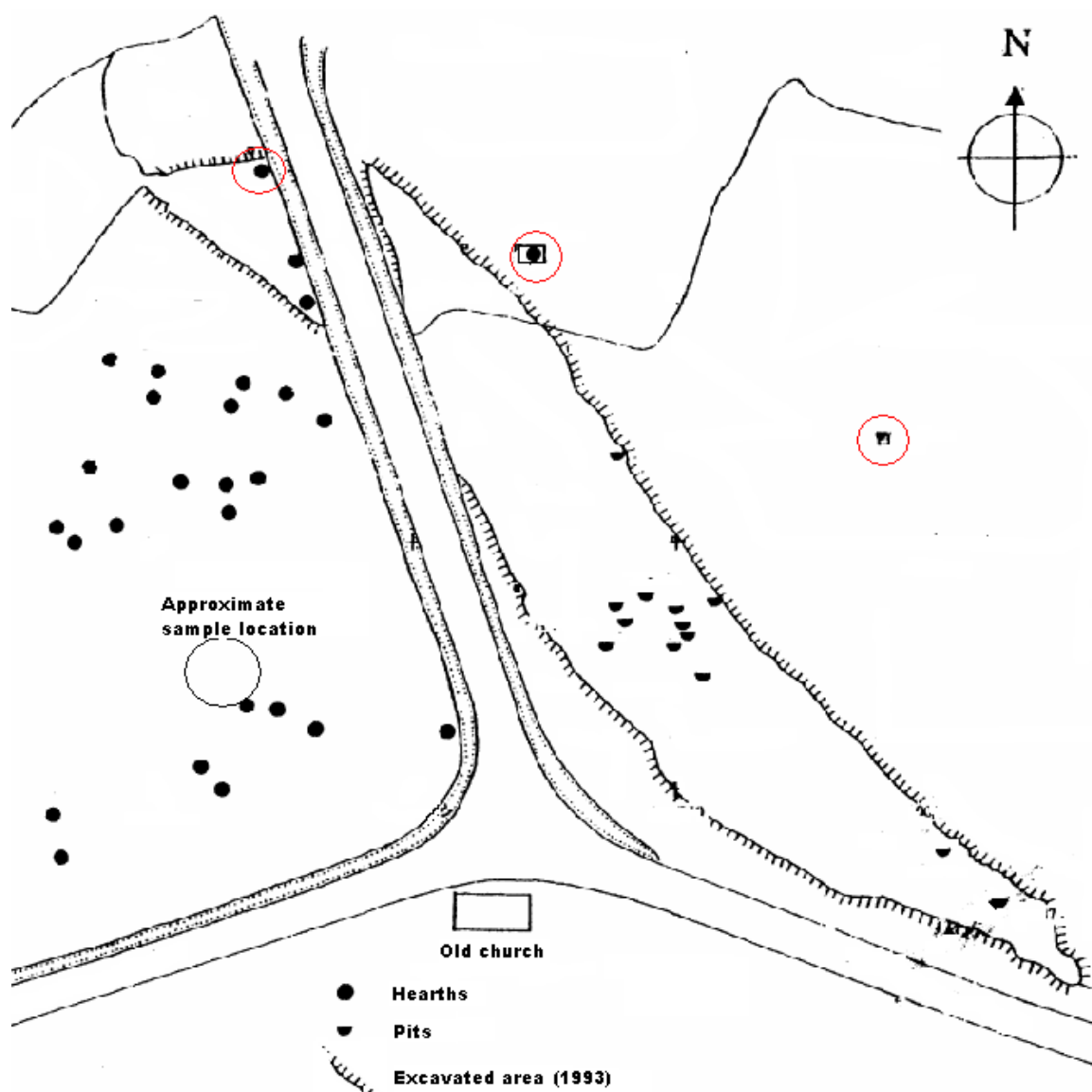
North Atlantic since prehistory (Branigan *et al.* 2002). In Norway evidence exists for this practice as early as the 8-9<sup>th</sup> century AD, where peat was valued not only as fuel but as animal bedding, which could subsequently be used as fertiliser on fields (Kaland 1986). The soil profile at Arvidsjaur shows a change from humified peat to fibrous peat at Sample 3 (Figure 13.3) and could signify that such a disturbance has occurred.

Few specimens were recovered from Sample 2. The assemblage includes aquatic beetles, damp ground dwelling Staphylinids, the waterside plant feeder *P. discolor* and the polyphagous weevil *O. nodosus*. There is a complete lack of woodland species. A riparian community still occupied the nearby lake shore, while open ground with grasses and heath vegetation now prevail in the tree-less bog. This assemblage probably relates to the time of expansion of the market place occurring in the 17/18<sup>th</sup> centuries, with intensified use on a year-round basis and increased numbers of people maintaining very open conditions.

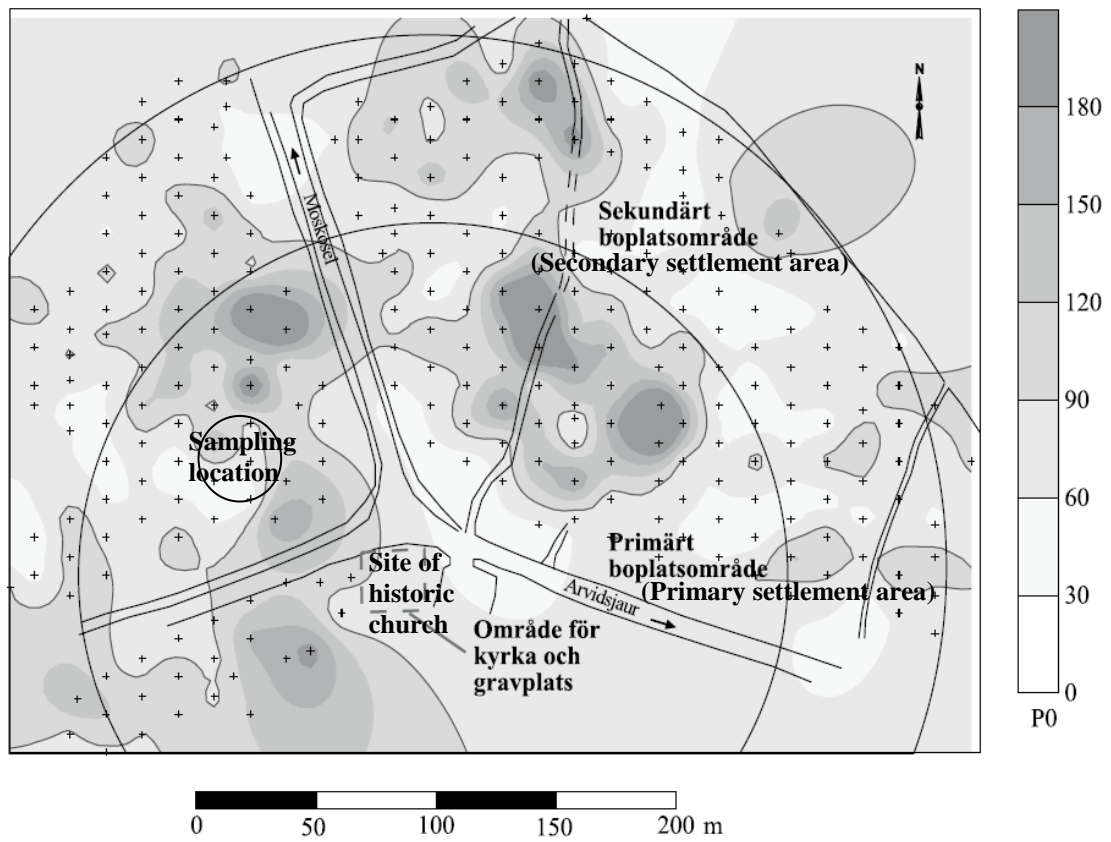
Two individuals of *Leptura* sp. and *Cryptocephalus* sp. indicate the re-establishment of deciduous trees in Sample 1. Covering the time of abandonment, Sample 1 may signify encroaching trees/shrubs on the recovering ground. Furthermore, woody fragments were found in this sample. As the site fell into disuse, recolonisation by deciduous trees is seen, paralleling the invasion by birch of the abandonment winter villages seen by Hicks (1993) and Carpelan and Hicks (1995).

Date	Archaeological/historical evidence	Postulated nature of activity at the site
1800s	Village relocated to modern site of Arvidsjaur.	Land now used for cultivation and pasture.
1606 AD	New church built on site	Permanent settlement
1500s	Church built on site Sámi artefacts found AMS dates from hearths	Periodic use as Sámi winter village
Pre 1500s	AMS dates from hearths dating from late 12 <sup>th</sup> century Term 'Dalvedis' used for the site, a name given to Sámi winter villages	Periodic use as Sámi winter village

**Table 13.2** Chronology of events at the site of Arvidsjaur (Bergling 1964; Liedgren 1997).



**Figure 13.5** The location of hearths and pits uncovered over several excavations at the Arvidsjaur site. Red circles indicate the hearths/pits where the oldest dates (12-14<sup>th</sup> century) have been found (Liedgren 1997).



**Figure 13.6** Elevated Phosphate levels at the Arvidsjaur site (Karlsson 2006).

SpeciesName	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Sample depth (cm)	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65
<b>Radiocarbon age</b>	1694- 1919 AD		1682- 1931 AD		39BC- 124 AD		350-52 BC						3361- 3100 BC
Faunal list													
Carabidae													
<i>Dyschirius globosus</i> (Hbst.)				1									
<i>Patrobus assimilis</i> Chaud.	1			1	1	2	4						
<i>Pterostichus strenuus</i> (Panz.)				2	2	5	6	8	2		2	1	1
<i>Pterostichus nigrita</i> (Payk.)							1	2				1	
<i>Amara lunicollis</i> Schiödte				1									
Dystiscidae													
<i>Hydroporus</i> cf. <i>umbrosus</i> (Gyll.)				4			5						
<i>Hydroporus</i> cf. <i>melanarius</i> Sturm				3	6	7	5	6	1				
<i>Hydroporus</i> sp.		1		5	10	16	24	11	7	5	3	9	8
<i>Agabus</i> sp.												1	1
<i>Rhantus exsoletus</i> (Forst.)					2								
Hydraenidae													
<i>Ochthebius minimus</i> (F.)		1		1							1		
Hydrophilidae													
<i>Coelostoma orbiculare</i> (F.)							2	3	1	2	2	3	1
<i>Enochrus ochropterus</i> (Marsham)			1		4	4	4	2	3		1	1	
<i>Enochrus</i> sp.	1			1	1	1			1	2		2	2
<i>Berosus luridus</i> (L.)								1					
Catopidae													
<i>Catops</i> sp.													2
Staphylinidae													
<i>Olophrum consimile</i> (Gyll.)						1			3				
<i>Olophrum rotundicolle</i> (Sahl.)		1		1	1	4	4	7	3	2	2	2	2
<i>Eucnecosum</i> cf. <i>brachypterum</i> (Grav.)		2	7	6	4								
<i>Acidota crenata</i> (F.)			1	1	1	2	2	3	1	1	1		

<i>Anthophagus alpinus</i> (Payk.)		1									
<i>Stenus</i> sp.	1		3	1		1		1	1		1
<i>Stenus</i> spp.		5									
<i>Euaesthetus bipunctatus</i> (Ljungh)								1			
<i>Lathrobium rufipenne</i> Gyll.		2			8		9				
<i>Lathrobium termitatum</i> Grav.	1	1	6	3	2	7	4	6	1	2	1
<i>Cryptobium fracticorne</i> (Payk.)		2		1	1			1			
<i>Philonthus nigrata</i> (Grav.)		3		1		4	1	1			
<i>Gabrius</i> sp.								2			
<i>Staphylinus erythropterus</i> L.									1		
<i>Quedius boops</i> grp. (Grav.)		5		1	1	1					
<i>Quedius</i> sp.	1								1		
<i>Mycetoporus</i> sp.	1					2					
<i>Tachyporus pusillus</i> Grav.		1									
<i>Atheta</i> sp.		1		1							
Pselaphidae											
<i>Bryaxis puncticollis</i> (Denny)		1									
<i>Bryaxis bulbifer</i> (Reich.)		1	1	1	1						
<i>Pselaphus heisei</i> Hbst.		1						1			1
Cantharidae											
<i>Rhagonycha testacea/limbata</i> (L.)/(Thoms.)						1					
Elateridae											
<i>Ampedus nigrinus</i> (Hbst.)				1	1						
<i>Sericus brunneus</i> (L.)		1		1							
<i>Ctenicera pectinicornis</i> (L.)										1	
<i>Athous</i> sp.									1		
Dryopidae											
<i>Dryops</i> sp.					1	2	1	1	1	1	3
Cryptophagidae											
<i>Atomaria</i> sp.		1						1			
Latrididae											
<i>Corticaria</i> sp.		1	1	1							

Coccinellidae												
<i>Coccinella</i> spp.			2									
SCarabidae												
<i>Aphodius nemoralis</i> Er.							1					
Cerambycidae												
<i>Leptura</i> (s.l.) sp.	1											
Chrysomelidae												
<i>Donacia obscura</i> Gyll.					1	3						
<i>Plateumaris discolor</i> (Panz.)		2		7	13	11	15	7	1	3	3	
<i>Cryptocephalus labiatus</i> (L.)				1	2	2						
<i>Cryptocephalus</i> sp.	1						1					
<i>Altica</i> sp.			3	3	5	10	7	9	4	3	6	6
<i>Chaetocnema concinna</i> (Marsham)								4	1			
Scolytidae												
Scolytidae indet.					1							
<i>Tomicus minor</i> (Hartig)			1	1								
<i>Pityophthorus lichtensteini</i> (Ratz.)					2							
Curculionidae												
<i>Deporaus betulae</i> (L.)				1				1		2		
<i>Otiorhynchus nodosus</i> (Müll.)		2	3	9	5	9	9	2				1
<i>Otiorhynchus ovatus</i> (L.)						1						
<i>Rhyncholus ater</i> (L.)						3						
<i>Dorytomus</i> sp.												1
<i>Notaris</i> sp.				1								
<i>Anthonomus phyllocola</i> (Hbst.)					1							
<i>Limnobaris dolorosa</i> (Goeze)											1	
<i>Micrelus ericae</i> (Gyll.)							1					

**Table 13.3** Arvidsjaur faunal list.



## 14 Quantitative Analysis

### 14.1 Detrended Correspondence Analysis

Statistical analysis was used to consider the extent to which numerical analysis can bring to light patterns in the insect fossil material that are not observed through a qualitative approach. The results of Detrended Correspondence Analysis mirror the trends observed through qualitative analysis. A full description of this method and its application in this research is included in section 7.8.2.

The resulting DCA plots (Figure 14.1, Figure 14.2, Figure 14.3, Figure 14.4 and Figure 14.5) present the relationship between samples and habitat groups. The distance/separation between points represents their similarity/dissimilarity and allows patterns in the data to be explored. At all sites S1 is the youngest sample.

The general patterns observed from DCA for each site can be summarised as follows:

*Sorsele:* The modern (S1) and lowest samples (S11 and 12) are the closest to the woodland category, and to the samples from Norrheden. Samples 7 and 9, in which environmental changes were suggested in connection with possible human activity at this site (Section 9.7), do not reflect a great deal of separation from the other samples in the resulting DCA plot. This suggests that the subtle environmental changes observed through careful qualitative analysis of the insect fauna during the Iron Age at the site are not as visible in the data when applying quantitative methods.

*Akkajärvi:* The uppermost samples tend towards heath/meadow, eurytopic and wetland habitats. The samples from Column A generally show closer associations with heath/meadow than the samples from Column B. All samples are distinct from those recovered from the natural Mid-Holocene woodland at Norrheden.

*Gammelhemmet:* The lowest sample shows closest association with the ‘woodland’ category. Sample 3, in which human activity is evident, is distinct from the other samples in that it is most closely allied to heath/meadow.

*Lycksele:* There is a discernible trend over time from woodland to heath/meadow.

*Arvidsjaur:* The samples are centred around the wetland category, reflecting the boggy lake-side locality from which they were recovered. A move from aquatic through to drier conditions, with the development of heath/meadow and woodland elements, can be seen particularly in Samples 3, 4 and 6. An open landscape with woody elements is indicated in the data at the site from the Early Iron Age.

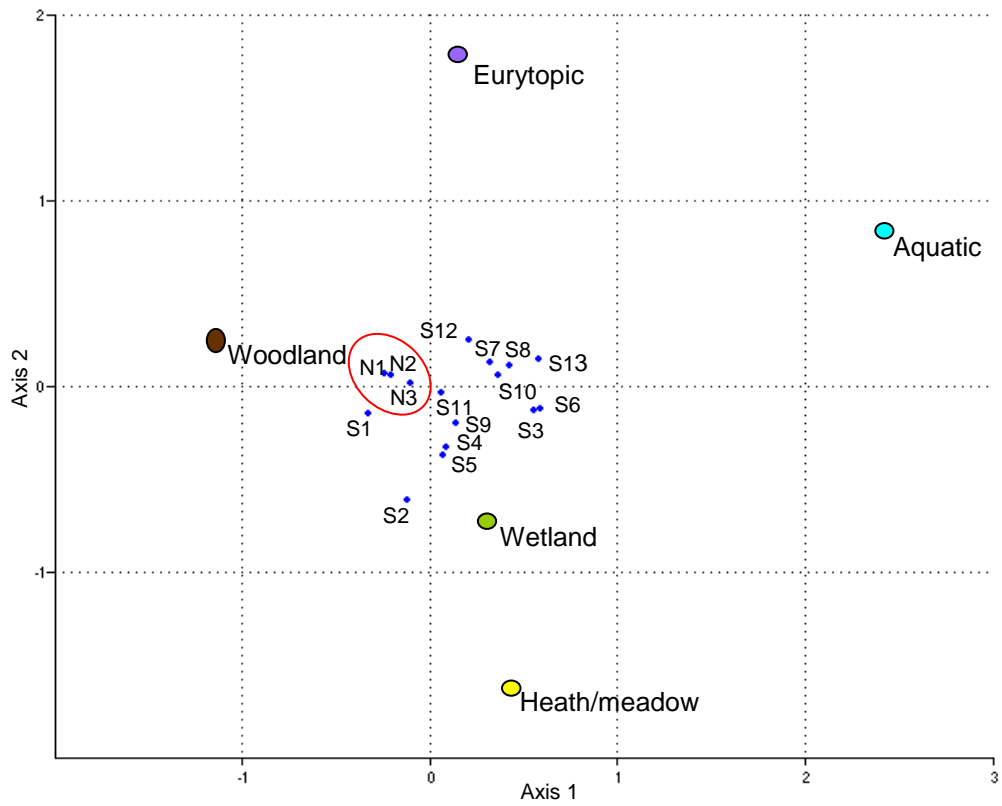
Certain general patterns are witnessed across several of the sites considered. In all of the DCA plots there is a clear clustering of the Norrheden samples (N1, N2 and N3) to the woodland category, and these samples are largely distinct from the other samples. This emphasises the distinctiveness of the Norrheden fauna, which included a much higher proportion of woodland species than at the majority of other sites in this study. The exception is Gammelhemmet, where the lowest sample had a high number of woodland species, and is clustered close to the Norrheden samples, demonstrating some similarities between the vegetation composition and structure of the Iron Age landscape at Gammelhemmet, and the Mid-Holocene forest at Norrheden.

A change is observed from initially wooded habitats e.g. at Gammelhammet, Lycksele and to a lesser degree Sorsele, or from open wet areas e.g. at Arvidsjaur and Akkajärvi, towards open bog/heath during the last few hundred years. These marked changes in the environment indicated through DCA occur during periods of human activity shown in the archaeological and/or historical record at the discussed sites.

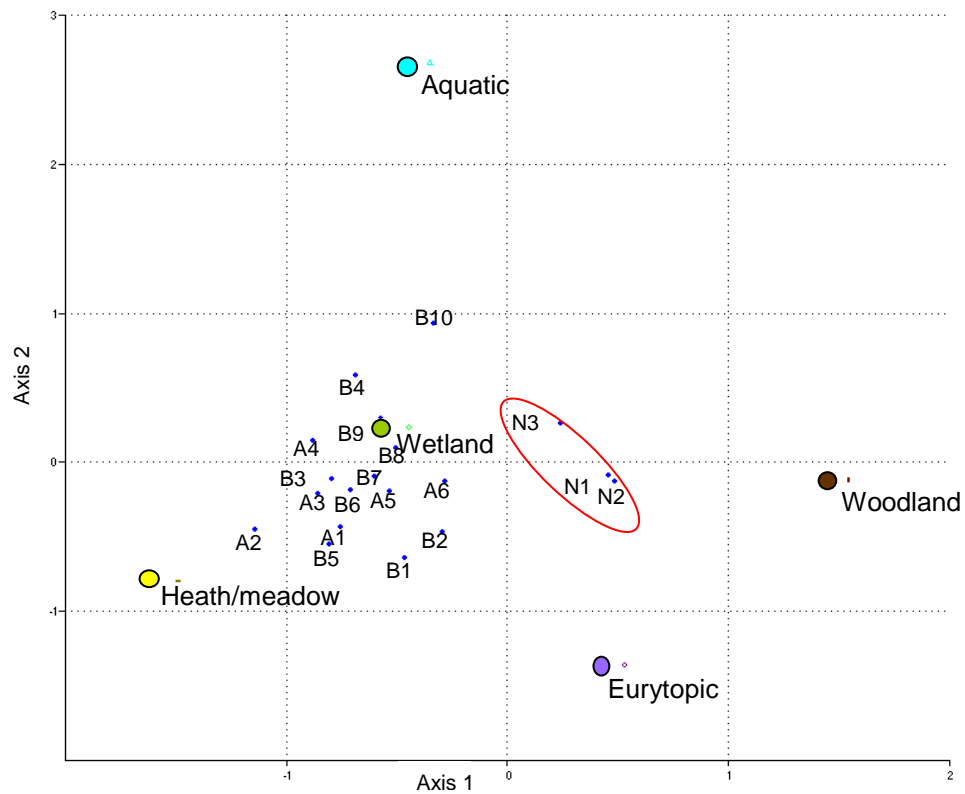
A consideration of these results, alongside the patterns observed from close qualitative analysis, indicates that trends in habitat types, in association with different types of

human disturbance, may be evident. Postulated periodic disturbances generally result in a mosaic landscape structure, which is demonstrated by the distribution of samples across habitat categories, while intense use by human groups leads to open landscapes, with the expansion of heath/meadow habitats being particularly marked. However in some cases, including the environmental changes witnessed in the insect fossil assemblages at Sorsele in Samples 7 and 9, where a change to more open habitats is apparent, the DCA plot does not reveal any notable changes in environment.

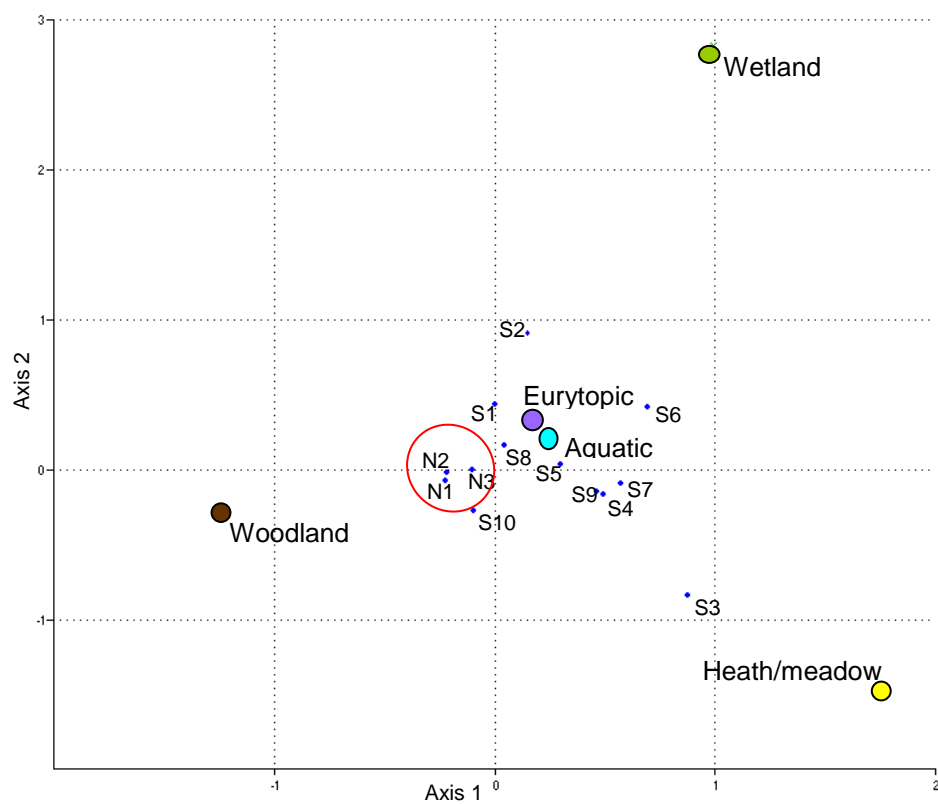
Overall, Detrended Correspondence Analysis has proved to be a functional tool in exploring trends in insect fossil data, mirroring the patterns of environmental change shown through qualitative analysis to a high degree. Nevertheless, subtle environmental changes may not be picked up using this technique, such as those observed at Sorsele where slight indications of more open wetland conditions were perceived through changes in species composition and abundances. This may in part be a restriction of using presence/absence data, avoiding abundance data, which results in the loss of information that may be of value. However, due to differences in preservation and sample sizes, and the fact that in several of the insect assemblages studied a species may be represented by only a single or few individuals, it was deemed most appropriate to avoid calculations based on abundance values. It is clear that quantitative analysis of insect fossil assemblages must be carried out with an understanding of the limitations involved, and may be a useful aid to, but not a substitute for, careful qualitative analysis.



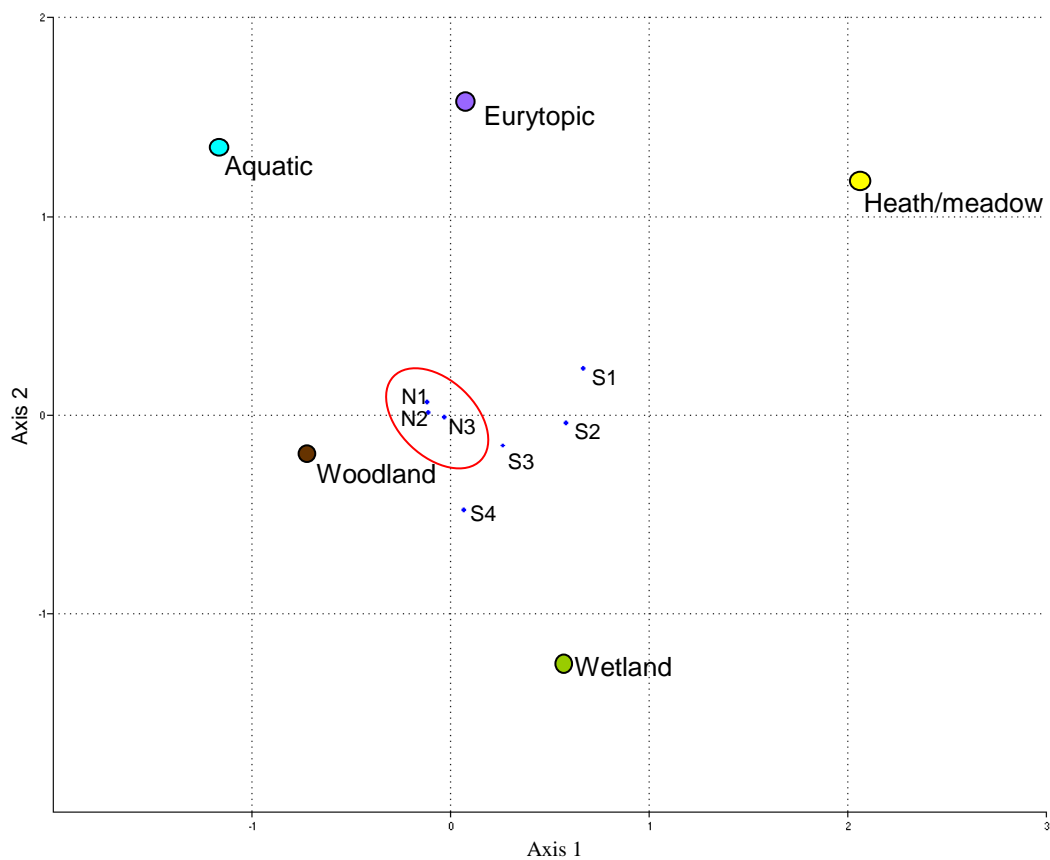
**Figure 14.1** Sorsele DCA. Sample 14 omitted as outlier (only 2 individuals).



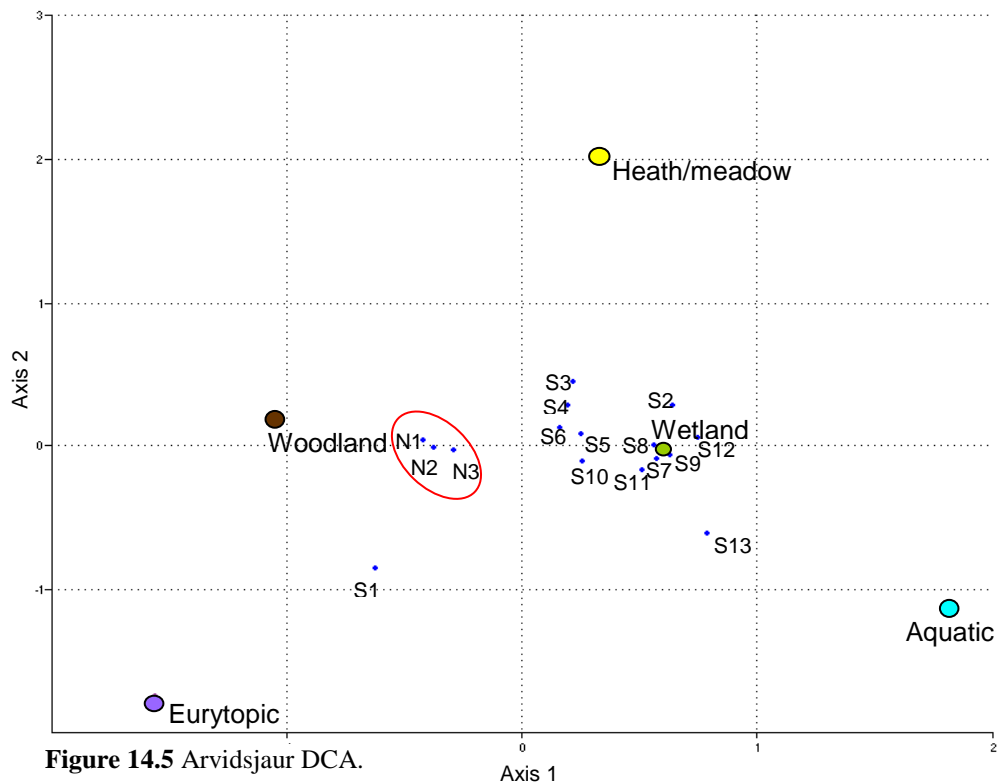
**Figure 14.2** Akkajärvi DCA.



**Figure 14.3** Gammelhemmet DCA.



**Figure 14.4** Gammelplatsen, Lycksele DCA



## 14.2 Biodiversity

The effects of past land use on biodiversity are currently not well understood in northern Sweden, this despite the fact that maintaining biodiversity is advanced as an important aim in current conservation strategies (Angelstam and Andersson 2001; Angelstam *et al.* 2004). Investigating the effects of particular types of past disturbance on species diversity is important as this provides evidence to inform current strategies that seek to sustain biodiversity. The time-depth inherent in this approach can supplement the findings of field studies based on current forest ecosystems, which provide only a limited snap-shot in time, and can thus be deployed to inform future management.

Some earlier studies show clear evidence that particular species which are tied to certain restricted habitats are being lost, owing to current forest management practices, namely

those which are dependent on dead or decaying wood, burnt or carbonised substances and on old trees (Berg *et al.* 1994; Siitonen and Martikainen 1994; Martikainen *et al.* 1996). However, species diversity in some instances may be higher at the present time, due to the increase in the range of species found in open habitats, on cut stumps and logs, and in managed forests more generally (Siitonen and Martikainen 1994; Martikainen *et al.* 1996).

The impacts of humans through time, in changing the landscape structure and in altering the vegetation cover, will have led to fluctuations in biodiversity across time as the intensity and/or nature of the human interventions varied. In some instances, human disturbance has been shown to enhance biodiversity. At Svartmosse, for example, insect species richness is linked with disturbance to the vegetation through grazing and cultivation, which created a mosaic landscape during the Viking Period, consisting of a semi-open woodland (Gustavsson *et al.* 2009b), and similarly at Stavsåkra, increased human activity resulted in diverse insect and pollen assemblages, a reflection of a more heterogeneous landscape structure (Gaillard *et al.* 2009a; Olsson and Lemdahl 2009a). Dung- and fire-dependent beetles and species of dry and exposed ground, for example, are found alongside indications of a forested environment, suggesting a mosaic landscape structure (Gustavsson *et al.* 2009b; Olsson and Lemdahl 2009a). However, from the 19<sup>th</sup> century at this location, the decline in both palynological diversity and insect species richness may suggest a change in the local environment related to the abandonment of the traditional agrarian system and to the development of a more homogenous landscape structure as a result of the abandonment of hay meadows, wood pastures and in the use of fire management (Gaillard *et al.* 2009a; Olsson and Lemdahl 2009a).

The following calculations of diversity were based on Fisher's alpha (see section 7.8.2 for more detail). The resultant patterns reflect both the number of species and the number of individuals from each of the study sites. When only a few individuals were present, e.g. in the upper samples of the columns from Akkajärvi, the results can be

misleading, as the underlying parameter may be the accumulation rate rather than a change in vegetation. In this case, these samples were grouped together.

The results from Norrheden reflect the well-established observation that biodiversity is high in old-growth natural forests, as has been discussed (Chapter 8). From the rest of the sites, faunal diversity is highest during periods when the insect fossil evidence suggests a high degree of landscape heterogeneity. This circumstance has generally occurred at sites during periods when they are postulated to demonstrate periodic human use. Similä and others (2002), for example, highlight the importance of young successional growth stages in sustaining biodiversity within boreal forests, as these locales act as hosts to species which reside in open and sunny habitats, and such environments should thus be given due conservation value.

Overall, the results presented here overall suggest that human disturbance at a certain level – namely intermittent use by low numbers of people – can be beneficial to the promotion of insect diversity by creating gaps in the forest and encouraging a range of successional states to be present.

#### **Norrheden**

<u><b>0-8cm</b></u>		<u><b>0-6cm</b></u>			<u><b>15-21cm</b></u>	
15.84	20.65	16.57	15.9	15.26	16.01	17.84

#### **Sorsele**

<u><b>S1</b></u>	<u><b>S2</b></u>	<u><b>S3</b></u>	<u><b>S4</b></u>	<u><b>S5</b></u>	<u><b>S6</b></u>	<u><b>S7</b></u>	<u><b>S8</b></u>	<u><b>S9</b></u>	<u><b>S10</b></u>	<u><b>S11</b></u>	<u><b>S12</b></u>	<u><b>S13</b></u>	<u><b>S14</b></u>
8.855	8.286	10.36	18.15	12.38	6.966	9.332	3.98	24.03	5.642	11.39	8.705	9.551	0

#### **Akkajärvi**

<u><b>B1,2,3,4,5</b></u>	<u><b>6</b></u>	<u><b>7</b></u>	<u><b>8</b></u>	<u><b>9</b></u>	<u><b>10</b></u>	<u><b>11</b></u>
9.264	18.71	10.12	17.95	12.01	8.271	5.565

*Table continues on next page*

<u><b>A1,2,3</b></u>	<u><b>4</b></u>	<u><b>5</b></u>	<u><b>6</b></u>
13.98	6.966	18.21	11.31



**Gammelhemmet**

<u>S1</u>	<u>S2</u>	<u>S3</u>	<u>S4</u>	<u>S5</u>	<u>S6</u>	<u>S7</u>	<u>S8</u>	<u>S9</u>	<u>S10</u>
16.1	0	3.84	17.01	17.77	23.6	14.06	15.54	13.19	24.03

**Lycksele**

<u>S1</u>	<u>S2</u>	<u>S3</u>	<u>S4</u>
53.28	7.076	8.934	10.49

**Arvidsjaur**

<u>S1</u>	<u>S2</u>	<u>S3</u>	<u>S4</u>	<u>S5</u>	<u>S6</u>	<u>S7</u>	<u>S8</u>	<u>S9</u>	<u>S10</u>	<u>S11</u>	<u>S12</u>	<u>S13</u>
0	7.867	9.332	22.96	10.69	12.68	7.934	8.987	8.347	13.03	15.51	9.49	8.271

**Table 14.1** Results of Fisher's alpha diversity index.

## 15 Synthesis and Discussion

This research project has studied natural environmental changes and human impacts in the interior north of Sweden over the last 8000 years using the insect fossil record as the primary approach. Bringing together the data from each of the six studied sites, the findings of the research can be considered in their entirety. Consideration of the results in their broader context illustrates how this research has furthered current understandings of environmental change in northern Sweden, and demonstrates that the project has made a valuable contribution to the field of archaeoentomology.

### 15.1 *The Mid-Holocene*

The insect fossil evidence from Norrheden, a natural boreal forest site dated to around 6000 BC, provided an opportunity to study the character of the undisturbed forest directly. The evidence from this site is invaluable in considering the structure and natural disturbance factors of pristine woodland, and in providing a natural base-line against which the later influence of human impacts can be assessed.

#### 15.1.1 The character of the natural landscape

Ecological studies carried out elsewhere in Fennoscandia at areas deemed natural, old-growth forest, have demonstrated certain characteristics, including a high volume of standing dead trees, the presence of fallen logs in variable states of decay, fire-damaged trees, hollow trees and mature trees, all as components of a forested landscape with multi-aged and mixed-species stands (Esseen *et al.* 1997; Siitonen *et al.* 2000). Today, many forests are clear-cut and the large trees are physically removed, and alongside the deliberate thinning of stands and fire suppression, there is generally a depletion of old and dead wood habitats in many contemporary Swedish forests (Linder and Östlund 1998; Siitonen *et al.* 2000).

Environmental reconstruction based on the insect fossil evidence from Norrheden show that the local Mid-Holocene forest was closed, with elements of old and rotting wood, and that a deep litter layer of decaying matter was host to a wealth of woodland species. Faunal assemblages recovered here are distinctly more diverse than any other insect fossil assemblage studied from northern Sweden. Most of the previously studied sites in northern Sweden are Lateglacial in age, and their insect faunas reflect tundra landscapes and the more severe climate events that prevailed during this time (Lindroth and Coope 1971; Robertsson and García Ambrosiani 1988; Aronsson *et al.* 1993; Lemdahl 1997a).

Early- to Mid-Holocene samples from Hemavan in Västerbotten, close to the Norwegian border, show a landscape distinctly different in character from Norrheden, with low numbers of tree-dependent species and a complete lack of species linked to old and rotting wood (Buckland 2007). The landscape around this site, situated in the Alpine zone, did not develop closed woodland conditions in the Early-Mid-Holocene, indicating that differences in local climate and topography were marked between this site and Norrheden, only 100km distant. Similarly, in comparison to the Late Holocene assemblages from other localities studied as part of this thesis, the character of the landscape at Norrheden is distinctly different, as will be discussed. At Gammelhemmet, considered below, there is some evidence that a wooded landscape with some ‘old forest’ elements akin to the Norrheden vegetation remained present until 2000 years ago.

Developing a clear understanding of the character of natural old-growth woodland is vital in informing conservation practices, enabling the elements which maintain biodiversity to be understood and imitated (Berg *et al.* 1994; Linder and Östlund 1998; Siitonen *et al.* 2000). In accordance with current understandings, this work highlights that an abundance of old, dead and rotting wood was indeed a valuable element characterising the natural boreal forest, and served as host to a wide range of insect species.

Species indicative of weakened trees, those stressed by fire, insect infestation, flooding, wind-throw, and/or of the presence of rotting wood, are found at Norrheden, including *Scolytus ratzeburgi*, *Cerylon ferrugineum* and *Tomicus piniperda*, whose presence is in accordance with what would be expected from natural boreal forest habitats (Koponen and Nuorteva 1973; Siitonen and Martikainen 1994; Martikainen *et al.* 2000; Ehnström 2001). However, obligate saproxylic species were found in much lower numbers than has been recorded from assemblages from southern Sweden, (e.g. Olsson and Lemdahl 2009a; 2009b) and Britain (e.g. Dinnin 1997). From Stavsåkra, in southern Sweden, Olsson and Lemdahl (2009a) recorded high numbers of species dependent on dead or decaying wood, particularly during the period 6450-4200 BC, the Mid-Holocene. *Melasis buprestoides* and *Prostomis mandibularis*, both quite rare, particularly the latter, are saproxylic species of rotted wood of considerable age, and were found in Early- to Mid-Holocene samples at Stavsåkra and the nearby site of Storasjö (Olsson and Lemdahl 2009a, 2009b). Many of the rare beetles recovered at the southern Swedish sites are favoured by fire (Olsson and Lemdahl 2009a, 2009b). *Agonum bogemanni*, a species confined to burnt areas, was found most frequently in Early- to Mid-Holocene samples from Stavsåkra and Storasjö, and is regionally extinct in Europe today (Olsson and Lemdahl 2009a, 2009b). A decline in saproxylic species synchronous with a period of lowered fire frequency was observed by Olsson and Lemdahl (2009a) at Stavsåkra c. 4000 -1400 BC. This suggests a link between numbers of saproxylic species and fire frequency.

A lack of charcoal at Norrheden may indicate that fire was not a significant disturbance factor in the local area during this period of the Mid-Holocene. The rarity of fires may have contributed to a lower abundance of species indicating damaged and dead wood, and the lack of rare pyrophilic species. Evidence of low fire frequency in the Mid-Holocene landscape, with low, or absent, fire-dependent species, has been interpreted from southern Swedish forests during periods within the Mid-Holocene (Greisman and Gaillard 2009; Olsson and Lemdahl 2009a; 2009b). Similarly from northern Sweden, pyrophylic species have not been found in assemblages at Hemavan, dating from this

time (Buckland 2007). At Makkassjön in northern Sweden, Korsman and Segerström (1998) recorded only a few peaks in charcoal in the Early-Mid-Holocene, contrasting with the frequency of charcoal recorded there beginning in the Late Holocene. This evidence suggests that natural fires were not a significant part of the disturbance regime of the Mid-Holocene forest in some areas, and this may in part be related to the prevailing colder and wetter climate (e.g. Greisman and Gaillard 2009; Olsson 2009, 36).

### **15.1.2 Climate**

The Mid-Holocene environment at Norrheden is represented in the insect faunal record as initially a heavily wooded, pine dominated forest. A move towards semi-open conditions is inferred only in the latest phase, around 6018-5887 BC. This may be due to local edaphic factors that were driving vegetation development at the site. This pattern fits with the regional vegetation development indicated by proxy evidence from other sites in the area, which suggests a shift from closed pine forest to more open, deciduous woodland (Engelmark 1996; Snowball *et al.* 2002; Hörnberg *et al.* 2005; Barnekow *et al.* 2008), and coincides with the established climatic model (e.g. Barnekow 2000; Korhola *et al.* 2000; Rosén *et al.* 2001; Seppä and Birks 2001; Snowball *et al.* 2002), suggesting that extensive forest prevailed during colder periods, and the spread of deciduous forest accompanied ameliorating temperatures. That a general pattern in vegetation development is being reconstructed from proxy evidence from sites across northern Sweden suggests that the changing climatic regimes over this period may have been significant enough to have had a widespread influence, and to be a major contributory factor directing vegetation development in the region. The MCR results do not indicate any major changes in temperature, but suggest that temperatures did not significantly exceed -14°C in winter and 13-15°C in summer during the period covered by the samples.

At Norrheden a change in hydrology was accompanied by the initiation of peat formation; both are witnessed in the soil profile and insect fossil record, which is

dominated at this horizon by beetles found in wet bogs and stagnant water (c. 8182-8035 BP). Large scale changes in topography, including lake formation as a result of isostatic uplift may have caused inundation, or local edaphic factors could have initiated the processes. Climatic conditions at this stage must have been favourable to water-logging, with wet conditions and low temperatures off-setting evaporation rates (Charman 2002). Climate is widely recognised as an important factor controlling peat landform development (Charman 2002; Tuittila *et al.* 2007; Andersson and Schoning 2010), and peat formation at Mid-Holocene sites across northern Sweden occurred during periods of climatic change. At Stordalen, Torneträsk, for example, peat inception occurred as a result of terrestrialisation and took hold at different rates across the mire, between c. 6000 BP and c. 4700 BP, during a period of warmer temperatures that are shown in proxy records from northern Sweden (Kokfelt *et al.* 2010). In the Scandes mountains, paludification contrastingly occurred during a period of lower temperatures occurring between c. 5500-5000 BP (Kullman 1995).

## **15.2 Late Holocene environmental change**

In the Late Holocene, the factors influencing the environment came to include human activity, and disentangling the variable effects of natural and human impacts within the palaeoecological record becomes increasingly difficult during this period. This research evaluates the visibility of natural processes, climate change and human impacts in the insect fossil record recovered from diverse sites during the Late Holocene.

### **15.2.1 Natural processes and climate change**

Despite the evidence gained from the insect fossil record regarding the key characteristics of the climate during the Lateglacial in northern Sweden (Aronsson *et al.* 1993; Lemdahl 1997a), only a single study of Holocene deposits has previously furnished climatic information (Buckland 2007), and no insect fossil faunas from Late Holocene sites have previously been studied. The range of appropriate comparanda are, to that extent, necessarily restricted.

At each of the studied sites from which evidence relating to the last few thousand years has been recovered (i.e. Sorsele, Akkajärvi, Gammelhemmet and Arvidsjaur), there are indications of environmental changes concurrent with a period of known climatic shifts c. 2500-2000 years ago. At Gammelhemmet, for example, the presence of moss-dwelling species alongside aquatic fauna and a decrease in woodland species could indicate *Sphagnum* bog formation/expansion around 2000 years ago. Peat formation at Akkajärvi also began at that time, with organic peat visible in the soil profile from Column B and beetle species typical of richly vegetated fens giving way to those more characteristic of peaty bogs. At approximately 2000-2500 BP at Arvidsjaur there was a diversification of aquatic and hygrophilous species, and the appearance of species found in stagnant water, such as *H. melanarius*, *E. ochropterus* and *B. luridus*. The disappearance of *Coleostoma orbiculare*, which has a TMaxLo of 12°C, was noted from the assemblage around 2000 BP. That declining temperatures may have played a part in its disappearance is possible, although this is by no means conclusive.

As has been discussed, evidence of human activity in the insect fossil and archaeological records at Gammelhemmet and Arvidsjaur indicates that human disturbances began at a slightly later date than the discussed hydrological changes which may indicate bog formation. At Akkajärvi some evidence of human impacts at the site may be evident in the insect fossil assemblages from 40cm in Column A, at a depth corresponding to the initiation of peat development in the Column B samples; however it is not clear if these samples are synchronous, and therefore it is not possible to determine whether human activity may have accompanied peat formation at the site or not. The evidence of an environmental change c. 2000 BP at Sorsele, with a predominantly open bog habitat represented and a reduction in species indicative of the local woodland, is similarly difficult to ascribe to purely natural or anthropogenic factors.

Evidence of colder wetter climates around the juncture of the Bronze and Iron Ages (c. 2500-2000 BP) has been recorded in proxy evidence from northern Scandinavia during

this time (Eronen *et al.* 2002; Grudd *et al.* 2002), and the abandonment of agricultural practices along coastal Västerbotten as a response to this climatic change is suggested by Englemark (1976). Furthermore, in a small mire in central Sweden, Andersson and Schoning (2010) found indications of peat formation, *Sphagnum* expansion, and a rise in the water table c. 2600 BP, which they observed as coinciding with environmental changes known from across northwestern Europe at this time, including increased humidity. Enhanced plaudification is recorded in the pollen record from Lake Svartkälstjärn, a small lake in Västerbotten, with increases in *Sphagnum* and *Cyperaceae* from c. 2500 BP (Barnekow *et al.* 2008). It may be the case that this was a period of particularly marked climatic deterioration in northern Sweden.

Climatic conditions may have driven the above-discussed peat development, or may simply reflect waterlogging and peat growth which was initiated by natural autogenic processes. It is widely known that human exploitation can affect peat landform development through altering the hydrology at a given site, through activities such as deforestation, fire, drainage and other forms of land management (Charman 2002). At Gammelhemmet and Arvidsjaur there is no clear indication of human exploitation at the sites at this time, suggesting that in these instances the initiation of peat growth was related to natural processes. It may be that in some cases the interplay of subtle human impacts, in combination with the widespread climatic deterioration known around the period c. 2500-2000 BP, were responsible for driving the discussed environmental changes.

Abandonment of the farm at Gammelhemmet occurred towards the end of the Little Ice Age, and could have become necessary in this low-lying setting, which would have been increasingly prone to frost. Nevertheless, there was no direct evidence of climatic cooling apparent in the species composition recorded here, or indeed from any of the study sites. The invisibility of the Medieval Warm Period and Little Ice Age in the insect fauna may have been attributable partly to the generally low numbers of species in



samples dating to the last few hundred years, as the paucity of MCR species can inhibit the utility of this method for detecting climate changes.

In proxy evidence from northern Scandinavia, the short-term climatic shifts of the Medieval Warm Period and the Little Ice Age have been detected in some instances, although these events appear to vary in timing and intensity across the study areas (Korhola *et al.* 2000; Grudd 2008; Bjune *et al.* 2009). Detection of Late Holocene climate changes in the fossil fauna is rarely achieved (e.g. Hellqvist and Lemdahl 1996; Wagner 1997). As human activity has intensified during the Late Holocene, it is often not possible to distinguish the climate signal from the overriding impacts of humans, further compounding this issue. It is thus possible that the more subtle and short term-changes will not be detected in the insect fossil records from this region, or indeed more widely, because they are masked by the prevailing impacts of human activity.

## **15.2.2 Signals in the insect fossil record.**

### **15.2.2.1 Periodic exploitation**

Investigating human impacts on the environment of the study area over time was one of the main aims of this research. In particular, it was postulated that different types of settlement and resource exploitation will have had varying degrees of, and discernibly different impacts on, the surrounding environment, and that this will be visible in the insect assemblages. Indigenous Sámi groups were expected to have had a detectable, but localised and short-term, impact on their environment while it was considered at the outset that the impacts of incoming farming groups on the environment would be severe.

The present writer sought to investigate palaeoecological data from a range of different site types, known to have been used by the Sámi to varying degrees of intensity and for different purposes. This approach enables a consideration of the varying impacts of the Sámi on the environment across sites used on a periodic basis, as well as an assessment of the visibility of Sámi activities in the insect fossil record. Furthermore, it was

postulated that periodic use of certain types of sites may not be readily distinguishable from natural changes in the insect fossil record, and there were thus opportunities to test this hypothesis.

For example, the decline in tree species and the increasing evidence for open conditions in Samples 7 and 9 at Sorsele, dating to the Iron Age, may have been influenced by climate and/or other natural processes; the archaeological evidence, however, suggests human use of the area during the period of the observed environmental changes. Exploitation of the local environment by the Sámi was likely to have taken place on an intermittent basis during this time (Bergman 1995), and it is thus possible that the subtle pattern of phases of use marked by slight changes in the composition of the ground vegetation, followed by the recovery of the local woodland, was associated with periodic human use of the site. This remains a tentative suggestion nonetheless, as factors such as climatic deterioration and other natural processes may have been forcible enough to create the subtle, but notable environmental changes witnessed at this time.

The insect fossil evidence from Akkajärvi suggests a shift to more open and drier conditions, accompanied by a reduction in damp leaf litter insect species during the last few hundred years. These changes may have occurred in synchrony with the beginning of extensive herding at the site and indicate that a combination of trampling by animals and associated erosion maintained open conditions around the site. Difficulties with chronological control at this site mean it is not possible to determine whether the evidence of open landscapes, indications of foul matter and the presence of dead wood species recorded from preceding samples could be related to earlier intensive reindeer herding practices, at a stage prior to the 17<sup>th</sup> century.

Species which exploit dung, among other substances, have been found in samples from Norrheden and Akkajärvi, however, only one dung beetle was recovered from across the study sites, at Arvidsjaur in a sample dating to around 2000 years ago. That only a solitary dung beetle has been recorded from across the six different study sites is

somewhat unexpected, since dung beetles have been recovered in insect fossil assemblages from a diverse range of natural and archaeological deposits in Sweden in the Late Holocene period (e.g. Hellqvist and Lemdahl 1996; Buckland 2007; Gustavsson *et al.* 2009a; Olsson and Lemdahl 2009a, 2009b). Reindeer were an important part of the economy from c. 2000 years ago onwards, and would have been kept in small numbers by many Sámi groups in the inland north of Sweden since the Late Iron Age (Aronsson 1991). However, outside of the *renvall* enclosures, the extent to which free grazing occurred in the immediate settlement area is not clear. In areas where grazing by small numbers of domesticated animals was spatially extensive, the accumulation of dung may not have been significant. This could imply that the rounding up of substantial numbers of reindeer was not being carried out at the study sites, and/or that grazing and herding were restricted to zones at a distance from the primary occupation area, from which the insect faunas were recovered. It is thus possible that grazing was highly localised in the landscape and the sampling regime employed in this study fell outwith these areas. Future investigations are needed to build on this hypothesis, and might focus more intensively on microscale spatial variations.

Furthermore, although the presence of species that can exploit dung, amongst other types of decaying organic matter, was recorded from the *renvall* at Akkajärvi, there is nonetheless a lack of dung beetles of *Aphodius* or *Geotrupes*, as might have been expected. It has been postulated that this may relate to one of several factors, including the removal of dung from the area, the use of smudge fires, or possibly the time of year that the *renvall* was in use.

Species associated with heath and/or open ground, including *Miscodera arctica*, *Strophosoma capitatum*, *Micrelus ericae*, *Byrrhus fasciatus* and *Amara lunicollis*, are noted in samples from around 1500-2000 years ago at Sorsele, Akkajärvi, Gammelhemmet and Arvidsjaur. The subtle indications of the development of heath seen at the study sites occur alongside pointers to landscape change, and in some cases these coincide with archaeological remains suggesting human exploitation. It is possible,

therefore, that the more open conditions and development of heathland within the landscape are connected with periodic Sámi land use.

Palaeoecological evidence from sites across northern Fennoscandia similarly indicate environmental changes, probably as a response to human disturbance, occurring c. 2500-2000 years ago (Hicks 1976; Engelmark 1976; 1978; Segerström 1990; Aronsson 1991; Barnekow *et al.* 2008). During this time in northern Sweden, changes in resource use occurred, with the emergence of small-scale reindeer herding constituting a major economic shift (Aronsson 1991). This implies that the intensification of the signal in the palaeoecological record at this time could be related to changes in the nature of settlement/exploitation.

Evidence at Arvidsjaur of a discernible link between open bog with elements of heath and human activity is clearer than that seen from the sites discussed so far. Species indicative of the expansion of open areas and the presence of heath, including *A. alpinus*, *Amara lunicollis*, and *Coccinella* spp. are found during the period covering postulated periodic human use of the locality, during the mid-late 1<sup>st</sup> millennium AD, possibly as a by-product of the site then being used by the Sámi as a winter village. It seems that periodic use of the area around Arvidsjaur by the Sámi and their reindeer had a more notable effect on the environment than that recorded elsewhere. Their impact here is more visible in the insect fossil record than is seen from other sites where periodic exploitation may have been taking place as part of a less intensive regime. Winter village sites are considered likely to have been used by larger numbers of people than sites exploited throughout the rest of the year; with an estimate by Hicks (1995) of 60-85 people comprising the Sijdda group at Einehllammet, for example. Palaeoecological studies thus indicate that the impact of human groups at Sámi winter villages can be more easily separated from natural environmental changes, due to the severity and character of the ecological signals detected (Hicks 1993; Carpelan and Hicks 1995; Karlsson 2006).

The clearly visible impacts revealed in the palaeoecological record from Sámi winter villages contrasts with the weaker signal occurring at sites with limited human occupation prior to their more regular use by large numbers of groups, the presence of more intermittent, small-scale use being not so easily distinguished from natural vegetation change. Hörnberg and others (2005), for example, could not confidently ascribe the subtle vegetational changes occurring from 8000 BP at Dumpokjauratj, Arjeplog, to human impacts, and elsewhere natural and human influences could not be convincingly distinguished at the Mesolithic site of Kvarnmyran by Segerström (1990). Aronsson (1991) found that the signal of human impacts in the pollen evidence from his reindeer herding sites was weak, prior to the expansion of herds that occurred in the 17<sup>th</sup> century. It is evident that separating subtle human disturbances taking place in relation to periodic exploitation from natural landscape changes in the palaeoecological record can be difficult. Nevertheless, there is a growing body of evidence suggesting that recognisable environmental changes can be linked to human activity during the 1<sup>st</sup> millennium AD.

At several sites in southern Sweden the spread of *Calluna* heath is documented in the Late Holocene, represented by the presence of species such as *Bradycellus ruficollis* (Steph.) and *Lochmaea suturalis* (Thoms.) (Olsson and Lemdahl 2009a, 2009b). This extension may be a result of fire and grazing regimes (Olsson 2009, 33). The establishment and expansion of heathland communities across the North Atlantic zone has been connected to a range of causal factors, including human activities and climate change, as well as autogenic factors (Kaland 1986; Bunting 1996; Tveraabak 2004; Hjelle *et al.* 2010). The appearance of species associated with heath at the northern Swedish sites studied in this research does not occur alongside those connected with fire and/or grazing.

The extent to which Sámi groups may have used fire to manage resources in the inland forest zone is not clear. Hicks (1993) indicates that the use of fire would have been detrimental in reducing forest resources around settlements, and was thus avoided. From

a study of the vegetation changes and fire patterns at earlier, Mesolithic, sites in the Arjeplog region (Hörnberg *et al.* 2005), it was noted that strong evidence of intentional burning was lacking and the charred particles encountered in the profile were considered most likely to be a result of cooking or the product of natural fires such as those caused by lightning strikes (Hörnberg *et al.* 2005). However, Hörnberg and others (1999) eliminate the possibility of domestic fires as the source of charcoal at their study sites in the Jokkmokk region, and note that the frequency of natural fires known in this area is low. The corresponding occurrences of charcoal with indications of human activity in the pollen and archaeological record, suggests that fires may have been used to improve winter grazing, encouraging the growth of lichens for wild, and later domestic, reindeer consumption (Hörnberg *et al.* 1999). It may be that different types of land use were employed, depending on the ecosystem, with the utilisation of fire at dry sites with abundant dwarf shrubs and feather mosses, encouraging the growth of lichen along the winter migration routes in the mountains as seen by Hörnberg and others (1999), while the use of fire was not advantageous at sites within the boreal forest zone.

Little evidence for fire-affected areas in their vicinity has been found at the study sites. Small fragments of charcoal were recovered from the Akkajärvi profile, where they were possibly of pre-Iron Age date; and charcoal from Sorsele occurred considerably earlier at c. 4763-4549 BC. Although possibly related to human occupation, these isolated fragments of charcoal do not provide, in the writer's opinion, enough evidence to point firmly towards human-induced fire events.

*Ampedus nigrinus* was found as a single occurrence in three samples - once in association with the clearance episode at Gammelhemmet; and in two Late Iron Age samples from Arvidsjaur. *A. nigrinus* is associated with dead and damaged wood and is commonly found in burnt tree stumps (Palm 1959; Koponen & Nuorteva 1973). At Stavsåkra, in southern Sweden, for example, all but one occurrence of this species is confined to Late Holocene samples, where they have been found alongside species associated with fire, heather and dung, in a landscape increasingly affected by both

livestock grazing and cultivation (Olsson and Lemdahl 2009a). Similarly at Storasjö, in southern Sweden, around 900 AD, a possible occurrence of *A. nigrinus* was registered alongside an increase in fire, dung and heath species (Olsson and Lemdahl 2009b). It may be that this beetle has been favoured by human activity, and its presence at both Gammelhemmet and Arvidsjaur thus reflects human disturbance in these landscapes.

The macroscopic charcoal evidence found at sites considered in this research is, in any case, reflective only of fires that took place in the immediate locality. It will be interesting in due course to consider the final results of the pollen and soil evidence from the same sites, currently being undertaken at the Universities of Aberdeen and Stirling respectively, which may provide comparative evidence of more regional fire activity.

### **15.2.2.2 Permanent settlement**

European settlement of the interior north was encouraged by the Lappmark Proclamation ‘Lappmarsplakatet’ of 1673, which allowed Finnish and Swedish citizens who settled in this area exemption from military service in addition to fifteen years of living tax-free (Nikolova 2007). There is good reason to believe that prior to this proclamation, European settlement here had been restricted in both extent and impact, with enticements necessary to encourage colonisation of this harsh landscape.

The state assumed that the considerable differences in economic practices between indigenous Sámi and European settlers would allow the co-existence of both groups within the landscape without difficulties (Kvist 1994). Sámi rights to the land were acknowledged in state policy, which stated explicitly that land used by tax paying Sámi was not to be colonised, and that their trading activities should not be disturbed. In the 18<sup>th</sup> century partitioning of the land, the Lappmark borders, which identified Sámi land as distinct from potential settlement areas, served to protect the Sámi territory (Nikolova 2007). Regulations issued in 1751 clarified the separation of coastal farming lands from the inland territories, which were to be used respectively by settlers and Sámi. As settlement expanded inland, however, these Lappmark zones became increasingly small

(Nikolova 2007). Agricultural practices, herding and hunting were all now taking place within the same landscape, and this caused conflicts over land use as European settlement intensified from the 18<sup>th</sup> century (Nikolova 2007).

This is an interesting time in the environmental history of the inland north, with the landscape supporting a new kind of resource use as agriculture was introduced; and yet until now, no investigations of the palaeoecological evidence associated with known European settlements in the northern interior of Sweden have been carried out. The writer sought to investigate the insect fossil evidence from sites of European settlement, considering both land use and environmental impacts in the local surroundings in the Västerbotten interior. Furthermore, the insect fossil evidence recovered from these sites can be considered in comparison to the palaeoecological evidence from those sites interpreted as having had periodic Sámi use.

High frequencies of charcoal were found at Lycksele, which could be associated with historic fire events. Aside from this, there is an absence of strictly fire- and dung-dependent species from the studied Late Holocene sites, which contrasts with the evidence found from sites in southern Sweden where successions of samples from the Late Holocene include both pyrophilic and dung-related species (Gustavsson *et al.* 2009a; Olsson and Lemdahl 2009a, 2009b). Although periods of low frequency do occur at southern Swedish sites, these studies show that both fire and grazing were integral elements in the environment during the Late Holocene, particularly as farming spread. This may suggest that fire was not being extensively employed as a method of clearance and land management at the studied sites further north.

However, slash-and-burn cultivation is known to have been employed by European settlers to enhance the productivity of farming settlement (Montelius 1960) - and it may be that these results, where direct evidence for such practices is distinctly muted, are unique to the study sites rather than a reflection of a more general pattern of low fire activity across the region, which would be difficult to reconcile with the prevalence of



slash-and-burn as a preparatory regime. It is interesting to note that the project in Greenland has found some evidence that suggests fire was not being used by Norse settlers, in contrast to what is widely thought regarding fire as a tool in land clearance (FOET Report 2011). The findings of current analysis of charcoal from soil and pollen samples being carried out as part of the project in the study area of northern Sweden will be of interest. It will be necessary for future studies to develop a fuller understanding of the impact and scale of fire activities, both natural and anthropogenic, in the Late Holocene landscape of northern Sweden, for hypotheses about the use and prevalence of slash-and-burn to be refined.

The insect fossil evidence does not indicate that land management practices, such as pasture management (Segerström *et al.* 1996; Östlund *et al.* 1997; Segerström and Emanuelsson 2002), the spreading of farm waste as fertiliser (Viklund 1998) and peat cutting (Lundberg 2002), which are recorded throughout Scandinavia, were being practiced at the study sites, at least on a sufficient scale for them regularly and unambiguously to be recorded in the records. Evidence of plaggen soils, that is, of the addition of manure and animal bedding to fields to improve soil quality, has been found at several of the sites studied in northern Sweden, including the site of Gammelhemmet (FOET Report 2011). The samples for soil analysis were taken from the area immediately surrounding the abandoned farm building, within the area considered to have been a field. This could suggest that land management practices such as manuring were being carried out, and that the insect fossil evidence was recovered from samples taken from an area outside the reaches of this. It will be necessary for future investigations to build on the current evidence, which will enable a fuller understanding of the land management practices used by settlers in the inland north, and the use of space around the farming establishments. The insect fossil evidence, considered alongside soils analysis, hints at the possibility that if soil enhancement was being carried out through the addition of animal waste, it was restricted to the fields used for cultivation in the area immediately surrounding the farm.

If European settlements were indeed being established in areas previously exploited by Sámi groups, large-scale clearances may not have been necessary at the outset, and the signal of European establishment may thus not be visible as an abrupt environmental change. At Arvidsjaur, for example, the use of the site as a winter village by Sámi groups may have resulted in a relatively open landscape within the local environment separate from and prior to the European settlement, marked by the 17<sup>th</sup> century church and marketplace establishment. Similarly at Gammelhemmet, evidence of a change to extensive open conditions occurs prior to the historic records of farming at the site. This could suggest that European farming here may have got underway before the legal records suggested it did, or could indicate that the area was more intensively exploited by Sámi groups before farmers settled at the site. This chronological discrepancy highlights that caution must be taken in attributing environmental changes to specific types of land use/ethnic groups in this environment.

Nevertheless, the presence of species indicative of agricultural land - such as *Clivina fossor* at Lycksele and *Chaetocnema hortensis* found at Gammelhemmet - may be the key to distinguishing between reindeer herding and farming-based livelihoods in the insect fossil record. The Sámi came to employ agricultural practices as part of their subsistence strategies, as has been indicated from c. 400 years ago in the Tjeggelvas Nature Reserve, northern Sweden (Josefsson *et al.* 2009), and from around the 18<sup>th</sup> century in the Jokkmokk area of the northern interior (Hultblad 1968). This means that indications of agriculture in the insect fossil record cannot always be straightforwardly equated just with European groups in the last few hundred years.

The results from the six study sites have been brought together, and considered in their broader context. It is apparent that a complex interplay of natural environmental change and human activity have been forces upon the landscape particularly from the Late Holocene period. Figure 15.1 presents the environmental changes inferred in the insect fossil evidence over the last 2500 years at the study sites alongside the climatic events recorded from other proxy data in northern Sweden and the archaeological/historical

evidence. This is intended to highlight how the evidence from the research presented here ties in with the main events occurring in the study area over the last 2500 years.

Timeline	The study sites				Additional information	
	Sorsele	Akkajärvi	Gammelhemmet	Lycksele	Arvidsjaur	Climate
0BP	Damp, relatively open	Open and damp				
500BP			Open, drier, fauna of grassland	Expansion of open areas, indication of pasture/agriculture Extensive fire Damp woodland	Lightly wooded bog	Little Ice Age
1000BP	Light woodland, drier areas				Open bog, with elements of drier heath	Medieval Warm Period
1500BP	Light, deciduous woodland Damp, lightly wooded	Reduction in aquatic and hygrophilous fauna Damp bog, some drier areas in surroundings, relatively open	Lightly wooded bog			Cool 'Dark Ages'
2000BP	Woodland decline, elements of heath expansion, drier		Open, damp bog			Warm 'Roman' period
2500BP	Open, wet		Old woodland		Mosaic landscape, damp bog, drier areas, and indications of wood	Cold and wet
					Richly vegetated wetland	
						Small-scale reindeer herding supplementing hunting and fishing Trapping pits in use

**Figure 15.1** Environmental changes in the insect fossil evidence over the last 2500 years various study sites. Climatic events and archaeological/historical evidence. Compiled from Aronsson (1991); Holm (1992); Snowball and others (2002); Karlsson (2006); Lunmark (2007); Barnekow and others (2008); Grudd (2008); Larsson *et al.* (2009).

### **15.3 The current landscape structure**

Evidence for natural vegetation changes, climate change, as well as changing topography and hydrology, have all been discussed, as have human impacts, demonstrating that in many areas of northern Sweden the current landscape structure is a product not only of a range of natural factors, but also of human disturbances. The concept of these landscapes being a natural wilderness, of landscapes untouched by human activity, is therefore often wrongly applied to substantial parts of the boreal forest zone of northern Sweden (Josefsson *et al.* 2010b); in many instances the prevailing sense of this being a wilderness is based on a false understanding of the ecological history of the land.

Berg and others (1994) noted that the number of threatened species of invertebrates is higher in southern Sweden than in the north. This is probably due, in part, to the higher number of species overall in the south. Stokland (1994) records a pattern of decreasing saproxylic species richness from south to north in Sweden, particularly for deciduous tree species. In total, only 5% of the saproxylic species encountered in that study had northern distributions (Stokland 1994). Furthermore climate plays a significant role in the distribution of flora and associated fauna (Bale *et al.* 2002; Bentz *et al.* 2010), and thermal tolerances of species further affect their spread along both north-south and altitudinal gradients (Angelstam and Andersson 2001; Ratcliffe 2005, 41; Eide and Aronsson 2010, 106).

In the south, human impact on the environment has been more profound, and has occurred over a longer period of time than in the north. Furthermore, the physical extent of protected land is less, and information on species representation is better than that in the north (Eide and Aronsson 2010, 106; Gärdenfors 2010, 57). All of these factors contribute towards the recognition that the absolute number of threatened species is higher in southern Sweden than in the north (Gärdenfors 2010, 57-58). That no species that are rare or now extinct were found at Norrheden suggests a noteworthy degree of

habitat continuity in this northern boreal landscape over time, partly due to the lesser and later human impacts in the north, enabling species survival in niche forest habitats more readily than has been possible in the fragmented, species poor, and dead-wood depleted forest habitats that long since replaced many old growth stands in the south (Björse and Bradshaw 1997; Linder and Östlund 1998).

At Lycksele, the northern part of the headland is currently conserved as an area of old growth forest. The insect fauna recovered in the southern part of the headland indicates that such woodland may once have prevailed further south on the islet, with the recovery of woodland species such as *Tomicus piniperda* restricted to samples that pre-date the historic fire events which occurred during the time of the establishment of the market town here. The fauna show that this once-wooded area has been altered by human activity, and the palaeoecological evidence from the time of intensive, settled use reveals that the impacts of concentrated human exploitation during the last few hundred years were substantial. Local fires were intensive, as is shown by the macroscopic charcoal found in many areas of the islet.

The implications of mistakenly identifying areas as wholly natural in character can greatly misinform current conservation practices. Areas identified as natural wildernesses have been used to inform the aims of modern conservation practices, including in forestry schemes (Fridman 2000; Siitonen *et al.* 2000; Similä *et al.* 2002) and Kuuluvainen (2009), showing that the current method of clear-cutting as a means to manage the forests is misaligned with understandings of natural disturbance regimes that occur in boreal forests, which involve a much more complex and subtle disturbance-succession cycle. Understanding past land use should be an integral component of ecological research in the boreal forests of northern Sweden, in order that current practices are aligned with a true understanding of what has previously happened to their ecologies.

Particularly in the inland north of Sweden, the effects of past human use on landscape structure and composition are not well understood. This research demonstrates that the impacts of humans on the landscape prior to permanent settlement were significant enough to drive localised changes to the environment, such as maintaining open conditions and possibly encouraging the expansion of heathland. This observation alters the common assumption that forests seemingly lacking a more recent history of farming or agricultural activity are thus ‘pristine’, with their current structure and composition unaffected by a human presence in earlier times (cf. Hicks 1995; Segerström 1997; Josefsson *et al.* 2010b).

Josefsson and others (2010a) have assessed the forest structure in areas where Sámi habitation is known from the archaeological record. They found that such forest stands contains higher numbers of young trees and less dead wood, and that such woodlands are more *Betula*-rich since being abandoned. This recolonisation of abandoned areas by *Betula* is a pattern seen at other sites in northern Scandinavia (Hicks 1993; Carpelan and Hicks 1995; Josefsson *et al.* 2010b). This pioneer woodland may be followed by the gradual recolonisation of such areas by coniferous woodland (Hicks 1993; 1995). At all the sites studied for this project, the current character of the landscape is generally open or lightly wooded with *Betula*; these sites occur in areas where the wider surroundings are characterised by more substantial woodland of older age, thus fitting with this pattern.

The insect fossil evidence from the study sites indicates that in many areas that were once heavily wooded, the make-up of the vegetation cover was first changed by indigenous groups. The stark contrast in vegetation structure and composition between the Mid-Holocene samples from Norrheden and the Late Holocene samples at all the other sites, is highly significant in highlighting just how drastically the vegetation cover has been altered over time. These changes are patently not the result of natural landscape changes.

The implications of these findings may touch upon current understandings of the northern Swedish landscape, supporting the growing understanding that in many areas the landscape is a product of thousands of years of human disturbance of varying levels of impact and intensity. Although the difficulties encountered in distinguishing early human-induced environmental changes from natural factors have led to only tentative conclusions being reached in this research, the results obtained may indicate that even in areas without associated archaeological evidence of exploitation, humans may have been altering the vegetation structure, and that a lack of visible signs at present of human activity does not necessarily equate with a purely natural landscape. This realisation will ensure more caution is deployed in interpreting the landscape; and that more care be taken when evaluating the apparent ‘naturalness’ of certain areas.



## **16 Conclusions**

### ***16.1 Environmental change in northern Sweden***

The overarching aim of this research was to explore environmental changes in the interior north of Sweden from the Mid-Late Holocene through an analysis of the insect fossil record. This work has produced evidence covering a time-span of several thousand years, bringing time-depth to the understanding of the interior boreal landscape of northern Sweden, a region that has rarely been studied in this manner before. By studying evidence from a natural base-line deposit, and from a range of sites with varying cultural histories, it has been possible to test a number of hypotheses relating to Mid-Late Holocene landscape dynamics, climate change and past human impacts in the inland region of northern Sweden.

The results obtained from the six study sites, their combined duration spanning over 8000 years, demonstrate that the environment has been shaped by both natural processes and the hand of humans. Dynamic processes of the Mid-Holocene, with rapid isostatic uplift and changing climate, were powerful forces in these landscapes, and the insect fossil evidence indicates that old-growth forest was established at Norrheden by c. 8000 BP. The data from this natural-base-line site provided a basis with which to assess the results from the other five sites, covering the Late Holocene period.

With the onset of the Late Holocene, the role of humans in transforming the landscape increased dramatically in northern Sweden. In order to explore the varying impacts of different types of exploitation, and to assess their visibility in the insect fossil record, sampling was carried out at five sites with different cultural histories.

The main conclusions of this research can be summarised as follows:

- Vegetation development at Norrheden may be linked to climate change, with a shift from closed pine forest, to more open deciduous woodland at Norrheden occurring in synchrony with a climatic regime of colder temperatures from c. 6000 BC followed by warming. MCR analysis, based on limited species, would suggest temperatures ranged between -14°C in winter and 13-15°C in summer.
- Comparison of the insect fossil assemblages from the base-line site of Norrheden with Late Holocene sites where human activity is evident, reveals a landscape that is distinctly different from the richly wooded environment of the undisturbed Mid-Holocene forest. Only at Norrheden, and Early Iron Age samples from Gammelhemmet, for example, are species indicative of old, rotting wood and extensive leaf litter found in significant numbers.
- *Ampedus nigrinus*, an elaterid which has been found in burnt tree stumps in Sweden, is the only beetle found in the studied insect fossil assemblages that shows a strong attraction to fire damaged habitats, although is also found in other habitats. Overall, the presently-available insect fossil and charcoal evidence does not provide strong indications of the use of fire by human groups in the immediate vicinity of the study sites.
- Only one individual dung beetle was found at the study sites, at Arvidsjaur c. 2000 BP. Grazing of domestic animals may have been highly localised in the landscape, and, with the exception of the *renvall* at Akkajärvi, the sampling areas selected for this study may have fallen outwith areas used as pasture and/or the rounding up of reindeer. At Akkajärvi the lack of obligate dung species may be connected with the intermittent or seasonal nature of site use.

- A mosaic landscape structure can be seen from the 1<sup>st</sup> millennium AD at several of the study sites, indicating the co-existence of open bog conditions and woodland habitats. Heath and/or open ground species such as *Miscodera arctica*, *Strophosoma capitatum*, *Micrelus ericae*, *Byrrhus fasciatus* and *Amara lunicollis* are present from around 2000 BP. It is difficult to ascertain whether the relatively open landscapes, sometimes with evidence of heath, are connected with periodic human activity or are purely natural in origin. If connected with human use, then the impacts of periodic exploitation can be seen to be subtle and localised, but notable enough to leave tell-tale signs in the insect fossil record. Furthermore, it is during the periods of mosaic landscape structure that biodiversity, calculated using Fisher's alpha diversity index, has been highest at most of the study sites. If this landscape structure had been created/maintained by Sámi exploitation, it would suggest that low level disturbance can be beneficial in promoting biodiversity, as measured by the insect fauna.
- During periods of intensive, permanent settlement recorded historically from around the 17<sup>th</sup> century at several of the study sites, the indication is of an open bog/heath landscape with little local woodland. These changes may be accompanied by the implementation of agriculture, indicated by the appearance of species commonly found in arable and pasture land, as were recovered at Gammelhemmet and Lycksele. The presence of species associated with open habitats, and with grassland/agricultural land, allows a degree of distinction to be observed between insect fossil assemblages from areas of permanent settlement and agricultural practices, and those from sites which were periodically exploited.
- Indications of environmental changes concurrent with a period of known climatic shifts c. 2500-2000 years ago, were interpreted from several of the study sites. The extent to which these environmental changes are connected with climate cannot be fully ascertained, and in some instances are more likely to have been

driven by human activity. Evidence of changing species distribution, or the presence of species with thermal tolerances indicative of climatic fluctuations, has not been explicitly documented in the Late Holocene faunal assemblages.

## 17 Future study

This research has generated the first insect fossil data from a succession of Holocene deposits in the middle boreal forest zone of northern Sweden, and also presents the first suite of insect fossil data from indigenous Sámi and European settled sites in the study area. The results have been significant in furthering understanding of landscape dynamics and human impact over the last 8000 years, allowing several hypotheses to be tested. Furthermore, this research raises some interesting questions and offers potential areas for further study concerning Holocene environmental changes in northern Sweden.

Initially, further investigation of insect faunal remains from natural contexts is needed in order to continue to build a fuller understanding of the landscape dynamics of the Mid-Holocene environment of northern Sweden. Currently the insect fossil evidence from Norrheden stands alone in providing a glimpse back in time, to the Mid-Holocene boreal forest of the Västerbotten interior. Future insect fossil studies that are undertaken from natural Mid-Holocene sites will contribute towards building an understanding of the natural vegetation development and climate in this region, and should also enable a fuller assessment of the variable influences of both broad scale regional, and small scale localised processes at work within the boreal forest zone.

Following from this, application of MCR, particularly at supposedly natural sites unaffected by human interference, is necessary to continue to assess the potential of insect fossils as indicators of past climatic conditions in northern Scandinavia. Furthermore, in sampling from sites with no indications of Late Holocene human activity, natural climatic changes during the Late Holocene may be investigated. This will help to determine whether insect fossil evidence has the potential to detect climatic changes during this period, and contribute towards a more fine-grained and localised understanding of the timing and extent of these events in northern Scandinavia.

The potential for using insect fossil evidence to study the nature of activities of periodic Sámi exploitation in the boreal forest was investigated. The results suggest that this approach could provide a means by which to detect subtle environmental change, although this can be difficult to confidently attribute to human disturbance. Building on this ground work, further analyses of insect fossil remains from archaeological sites could offer clarity regarding the extent of Sámi environmental impacts at different site types e.g. seasonal settlements, reindeer herding sites (*renvall*) and exploitation areas. Studying the insect fossil remains from sites immediately adjacent to an area of settlement and from an area at some distance from the settlement, assumed to be outwith the sphere of anthropogenic influence but which is typified by similar local natural conditions, would help to develop a clearer picture regarding the variable influences of climate and periodic Sámi exploitation in northern Scandinavia. Furthermore, such studies, in combination with extensive radiocarbon dating, could contribute towards an understanding of the periodicity of use at such sites in the inland north, where current theories are based primarily on available historical information and limited palaeoecological evidence.

Further investigation of archaeological deposits will enable an evaluation of the extent of fire and grazing disturbances throughout the Late Holocene in northern Scandinavia, and may clarify aspects of Sámi land use, including whether fire was intentionally utilised as a means of vegetation management in some localities while restricted in others, and the spatial extent and impacts of grazing around settlements. Analysis of insect fossil evidence alongside other proxies, including pollen and charcoal evidence, can provide a means by which fire in the landscape can be detected using the variable advantages of the different methods now available, and which may provide evidence regarding the use of fire at both a local and regional level.

Differences existed in the focus of the subsistence strategies employed by early Sámi groups across northern Sweden, with groups along the coast employing fishing, hunting and trapping as the main forms of subsistence, while the inland areas, although also

incorporating aspects of hunting and fishing, depended on small groups of domesticated reindeer from around the Late Iron Age (Manker 1964; Wheelersburg 1991; Aronsson 1991; Flint 2010). It would be of interest to investigate the palaeoecological evidence from these different economic spheres, considering similarities/differences in aspects of subsistence and land use strategies, and the environmental impacts of these groups, relating to specific localised conditions. Following from this, the analysis of insect fossil remains from indigenous Sámi sites across Sápmi, where groups focused on different forms of resource use depending on local circumstances (Tegengren 1952; Hultblad 1968; Odner 1992), could reveal interesting patterns of Sámi subsistence and environmental impacts across the whole of Sápmi.

Palaeoecological studies from farming sites in the interior north will, in due course, obtain more information about the resource management regimes of early settlers, potentially including the use of methods such as slash and burn, the manuring of fields and the development of irrigation systems, as seen at other farming sites in central and southern Sweden or, just as interestingly, the lack of evidence regarding such complex land use practices. This will necessitate sampling from the immediate areas of exploitation, a process which is restricted by various real-world issues, including the identification of historic activity areas, access, and preservation. This approach may also reveal more specific information about living conditions at settled farming sites, and the use of space surrounding the farm themselves.

As the results of such studies continue to unfold, it may be possible to discern a signal for permanent settlement as distinct from one indicative of periodic exploitation practices, building on the patterns witnessed in the research presented here.

## Appendix I – Further information on the identification of selected species

### ***Arpedium quadrum***

This species was separated from *Eucnecosum* by the shiny, coarsely punctured thorax and elytra which lacked shagreen (Munster 1933). Unfortunately no modern comparable specimens were available for comparison, however close observation highlights the characteristic features discussed by Munster (1933). The elytra are parallel sided. The thoraces found were variable in shape and in punctuation. Most were quite squarish, with course punctures, but one had a widening towards the front of the thorax and the punctures were sparser and slightly finer. This variation is noted by Munster (1933).

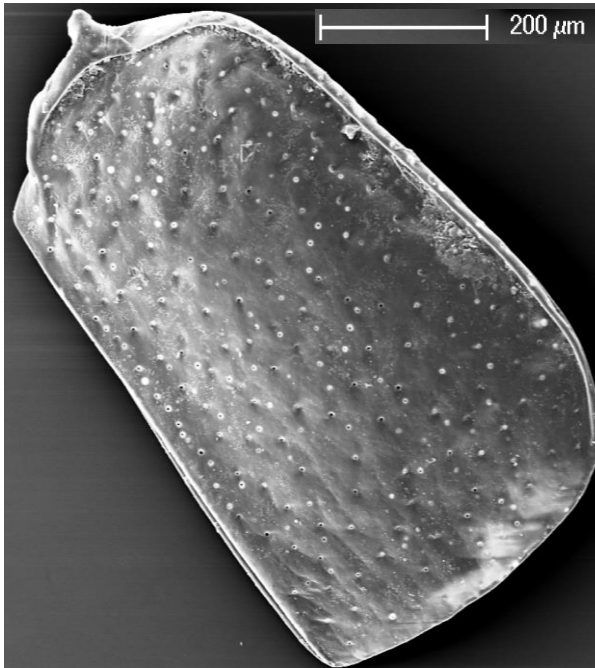
### ***Eucnecosum***

Two species are known from the area of Västerbotten and Norrbotten today, *E. brachypterum* and *E. brunnescens*, while *E. norvegicum* is found in other regions of northern Sweden although absent from the study area. Difficulty in identification was heightened by the absence of modern comparative specimens of both *brunnescens* and *norvegicum*.

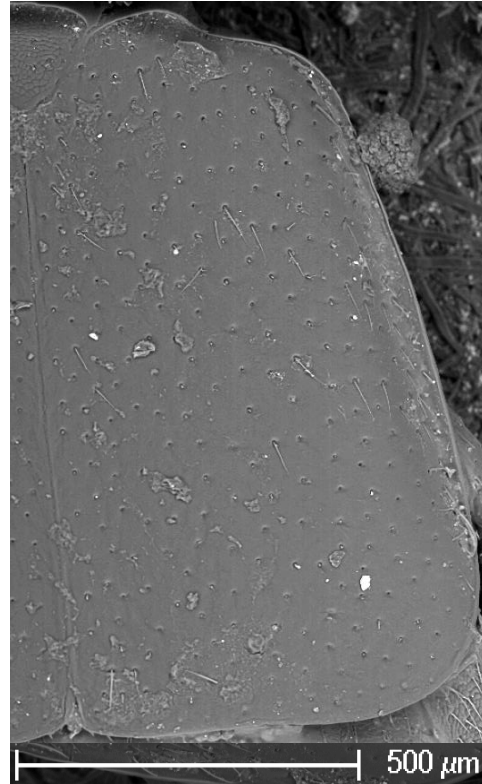
The variation found among species of *E. brachypterum* and *E. norvegicum*, and their similar characteristics, can make them difficult to distinguish, especially without the characteristic fortibia (Campbell 1984; Munster 1933; Freude *et al.* 1964). However, several other defining characteristics can be studied on the sub-fossil remains. The presence/absence of small punctures between the eyes (Munster 1933) is one such characteristic. Careful use of the high powered microscope suggested a lack of such points. Furthermore the ‘channel’ found on the thorax of *E. norvegicum* is not seen. *E. brunnescens* is smaller in size, with short elytra and more coarse and sparse punctuation (Munster 1933; Freude *et al.* 1964). The characteristics of the recovered elytra fit most securely with *E. brachypterum*, which generally has more fine, regular punctuation than any of the other species, although variation occurs within the species (Munster 1933;



Freude *et al.* 1964). These similarities are seen in the SEM images of the fossil and modern specimens. The absence of *E. norvegicum* in the area today provides some additional support for this.



SEM photograph of fossilized elytron of *Eucnecosum* cf. *brachypterum*.



SEM photograph of the modern elytron of *Eucnecosum brachypterum*.

### ***Lathrobium***

Of this genus, 11 species are currently found in the study area (Gustafsson 2005). Of the *Lathrobium* remains recovered, identification of two species has been attempted, however other specimens could not be confidently taken to species level as only the elytra were recovered, proving uncharacteristic in themselves.

*L. rufipenne*

The finding of a quadrangular head, densely covered with punctures, and with a thick neck suggested *Lathrobium* cf *rufipenne* (Lohse 1964; Lott and Anderson 2011).

*L. terminatum*

Some of the elytra display ‘flashes’ of yellow at the hind angle, separating them from the similar species *L. quadratum*. Some elytra do not display this characteristic, but have the same shiny, coarsely punctured and uneven surface (Lohse 1964; Lott and Anderson 2011). The small size and slight form of the head, thorax and elytra similarly point towards this species.



0.5mm

Densely punctured head of *Lathrobium rufipenne*.

***Hydroporus***

*Hydroporus* can be a complicated genus, with many of the species variable in shape, colour and size (Joy 1976; Foster and Friday 2011). However, where remains of the head, thorax and elytra were found, identification was attempted to species level, often with the aid of the diagnostic metacoxal plate with process and/or the prosternal process. This includes *Hydroporus tristis*, *H. morio* and *H. melanarius*. Characteristic features

include the outline of the body shape, the density and strength of punctuation, the patterns of beading on the pronotum and elytra, the shape of elytra at apex and shoulder, and the variations in the metaxocae as illustrated in (Nilsson and Holmen 1995). In some cases the parts were not sufficiently diagnostic to be confidently distinguished from other species and so have been left at genus level.

### ***Altica***

Characteristic parts (in the absence of aedeagus) include the frontal calli, elytral ridge, pronotum furrows and impressions and shape at hind angles, elytral punctuation and microreticulation (Doguet 1994, Warchałowski 2003). Although some of these parts were recovered, confident identification remained difficult, because of the lack of comparable specimens.

## Bibliography

- Aaby, B. (1976). Cyclic climatic variations in climate over the past 5, 500 yr reflected in raised bogs. *Nature*, 263, 281-284.
- Ågren, J. and Svensson, R. (2006). Land uplift model and system definitions used for the RH 2000 adjustment of the Baltic levelling ring. *The 15<sup>th</sup> General Meeting of the Nordic Geodetic Commission, Copenhagen, 29 May – 2 June*, 1-9.
- Alexander, K. N. A. (1994). *An Annotated Checklist of British Lignicolous and Saproxyllic Invertebrates*. National Trust Estates Advisors' Office, Cirencester (Draft).
- Alexander, K. N. A. (2002). *The invertebrates of living and decaying timber in Britain and Ireland - a provisional annotated checklist*. English Nature Research Report 467, Peterborough (142pp).
- Alexandersson, H. and Eggertsson Karlström, C. (2001). Temperaturen och nederbörden i Sverige 1961-1990. Referensnormaler - utgåva 2. *Meteorologi* no. 99. SMHI, Norrköping.
- Almquist-Jacobson, H. (1995). Lake-level fluctuations at Ljustärnen, central Sweden and their implications for the Holocene climate of Scandinavia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 118, 269-290.
- Andersen J. (1993). Beetle remains as indicators of the climate of the climate in the Quaternary. *Journal of Biogeography*, 20, 557-562.
- Andersson, S. and Schoning, K. (2010). Surface wetness and mire development during the late Holocene in central Sweden. *Boreas*, 39 (4) 749-760.
- Angelstam, P. and Andersson, L. (2001). Estimates of the needs for forest reserves in Sweden. *Scandinavian Journal of Forest Research*, 16 (S3) 38-51.
- Angelstam, P., Boutin, S., Schmiegelow, F., Villard, M-A., Drapeau, P., Host, G., Innes, J., Isachenko, G., Kuuluvainen, T., Mönkkönen, M., Niemelä, J., Niemi, G., Roberge, J-M., Spence, J. and Stone, D. (2004). Targets for boreal forest biodiversity conservation – a rationale for macroecological research and adaptive management. *Ecological Bulletins*, 51, 487-509.
- Aravena, R., Warner, B. G., Charman, D. J., Belyea, L. R., Mathur, S. P. and Dinel, H. (1993). Carbon isotopic composition of deep carbon gases in an ombrogenous peatland, northwestern Ontario, Canada. *Radiocarbon*, 35 (2) 271-276.

- Arnborg, T. (1990). Forest types of northern Sweden. Introduction to and translation of "Det nordsvenska skogstypsschemat". *Vegetatio*, 90, 1–13.
- Aronsson, K.-Å. (1991). *Forest reindeer herding AD 1-1800: an archaeological and paleoecological study in northern Sweden*. Doctoral thesis, Department of Archaeology, University of Umeå.
- Aronsson, K.-Å. (1994). Pollen evidence of Saami settlement and reindeer herding in the boreal forest of northernmost Sweden an example of modern pollen rain studies as an aid in the interpretation of marginal human interference from fossil pollen data. *Review of Palaeobotany and Palynology*, 82, 37-45.
- Aronsson, M., Hedenäs, L., Lagerbäck, R., Lemdahl, G. and Robertsson, A.-M. (1993). Flora och fauna i Norrbotten för 100 000 år sedan. *Svensk Botanisk Tidskrift*, 87, 241-253.
- Ashworth, A. C. (2001). Perspectives on Quaternary Beetles and Climate Change. In: Gerhard, L. C, Harrison, W. E. and Hanson, B. M. (eds.) *Geological Perspectives of Global Climate Change*. American Association of Petroleum Geologists Studies in Geology 47, Tulsa, Oklahoma, 153- 168.
- Atkinson, T. C., Briffa, K. R., Coope, G. R. (1987). Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains. *Nature*, 325, 587–592.
- Atkinson, T. C., Briffa, K. R., Coope, G. R., Joachim, J. M. and Perry, D. W. (1986). Climatic calibration of Coleopteran data. In B. E. Berglund (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. J. Wiley and Son, Chichester, 851-858.
- Atty, D. B. (1983). *Coleoptera of Gloucestershire*. Cheltenham.
- Austarå, Ø., Annila, E., Bejer, B. and Ehnström, B. (1984). Insect pests in forests of the Nordic countries 1977-1981. *Fauna Norvegica*, B31, 8-15.
- Axelsson, A-L, and Östlund, L. (2001). Retrospective gap analysis in a Swedish boreal forest landscape using historical data. *Forest Ecology and Management*, 147, 109-122.
- Backlund, H. O. (1945). Wrack Fauna of Sweden and Finland. *Opuscula Entomologica Supplement* 5.
- Bakke, A. (1958). Mass Attack of *Brachonyx pineti* Payk. (Col., Curculionidae) on Pine Forests in Norway. *Meddelelser fra det Norske Skogforsoksvesen* 50, 125-142.

- Balachowsky, A. (1949). Coleopteres Scolytides. *Faune de France* 50, P. Lechevalier, Paris.
- Bale J.S., Masters G.J., Hodkinson I.D., Awmack C., Bezemer T.M., Brown V.K., Buttefield, J., Buse, A., Coulson, J. C., Farrar, J., Good, J. W., Harrington, R., Hartley, S., Jones, T. H., Lindroth, R. L., Press, M. C., Symrnioudis, I., Watt, A. D. and Whittaker, J. B. (2002). Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. *Global Change Biology*, 8, 1–16.
- Barnekow, L. (1999). *Holocene vegetation dynamics and climate changes in the Torneträsk area, northern Sweden*. Doctoral dissertation, Department of Quaternary Geology, Lund University.
- Barnekow, L. (2000). Holocene regional and local vegetation history and lake-level changes in the Torneträsk area, northern Sweden. *Journal of Paleolimnology*, 23, 399-420.
- Barnekow, L., Bragée, P., Hammarlund, D. and St. Amour, N. (2008). Boreal forest dynamics in north-eastern Sweden during the last 10000 years based on pollen analysis. *Vegetational History and Archaeobotany*, 17, 687-700.
- Barrett, J., Hall, A., Johnstone, C., Kenward, H., O'Connor, T. and Ashby, S. (2007). Interpreting the plant and animal remains from Viking-age Kaupang. Kaupang in Skiringssal. Skre, D. Aarhus, Aarhus University Press, 1, 283-320.
- Beach, H. (1981). *Reindeer-Herd Mangement in Transition. The Case of Tuorpon Saameby in Northern Sweden*. Uppsala Studies in Cultural Anthropology 3. Uppsala.
- Beaver, R. A. (1967). Notes on the fauna associated with elm bark beetles in Wytham Wood, Berks. I. Coleoptera. *Entomologist's monthly Magazine*, 102, 163-170.
- Behrensmeyer, A. K., Kidwell, S. M. and Gastaldo, R. A. (2000). Taphonomy and paleobiology. *Palaeobiology*, 26, Supplement 4, 103-147.
- Bengtson, S.-A. (1981). Terrestrial invertebrates of the Faroe Islands: III. Beetles (Coleoptera): Checklist, distribution, and habitats. *Fauna Norvegica*, B28, 52-82.
- Bennike, O., Houmark, Nielsen, M., Böcher, J. and Heiberg, E. O. (1994). A multidisciplinary macrofossil study of Middle Weichselian sediments at Kobbeltgård, Møn, Denmark. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 111, 1-15.

- Bentz, B. J., Régnière, J., Fettig, C. J., Hansen, E. M., Hayes, J.L., Hicke, J.A., Kelsey, R. G., Negrón, J. F. and Seybold, S. J. (2010). Climate change and bark beetles of the Western United States and Canada: direct and indirect effects. *BioScience*, 60 (8) 602-613.
- Berg, Å., Ehnström, B., Gustafsson, L., Hallingbäck, T., Jonsell, M. and Weslian, J. (1994). Threatened plant, animal, and fungus species in Swedish forests: Distribution and habitat associations. *Conservation Biology*, 8 (3) 718-731.
- Bergling, R. (1964). *Kyrkstaden I Övre Norrland: Kyrkliga, merkantila och judiciella funktioner under 1600– och 1700–talen*. Kungl. Skytteanska samfundets handlingar, 3.
- Berglund, B. E., Barnekow, L., Hammarlund, D., Sandgren, P. and Snowball, I. F. (1996a). Holocene forest dynamics and climate changes in the Abisko area, Northern Sweden: The Söndersson model of vegetation history reconsidered and confirmed. *Ecological Bulletins*, 45, 15-30.
- Berglund, B. E., Björse, G. and Liljegren, R. (1996b). From the Ice Age to the present day. In Gustafsson, L. and Ahlén, I. (eds.) *Geography of Plants and Animals*. National Atlas of Sweden, SNA Publishing, 14-24.
- Berglund, B. E., Lemdahl, G., Liedberg-Jonsson, B. and Persson, T. (1984). Biotic response to climatic changes during the time span 13,000-10,000 B.P. - a case study from SW Sweden. In Möner, N. A and Karlén, W. (eds.) *Climatic Changes on a Yearly to Millennial Basis*. D. Reidel, Dordrecht, 25-36.
- Berglund, M. (2011). The highest postglacial shore levels and glacio-isostatic uplift pattern in northern Sweden. *Geografiska Annaler: Series A, Physical Geography (online)* doi: 10.1111/j.1468-0459.2011.00443.x
- Bergman, I. (1995). *Från Dödudden till Varghalsen. En studie av kontinuitet och förändring inom ett fångstsamhälle i övre norrlands inland, 5200 f. Kr – 400 e. Kr*. Studia Archaeologica Universitatis Umensis 7. Umeå.
- Bergman, I., Olofsson, A., Hörnberg, G., Zackrisson, O. and Hellberg, E. (2004). Deglaciation and colonisation: pioneer settlements in northern Fennoscandia. *Journal of World Prehistory*, 18, 155–177.
- Bergman I., Pässe T., Olofsson, A., Zackrisson, O., Hörnberg, G., Hellberg, E. and Bohlin, E. (2003). Isostatic land uplift and Mesolithic landscapes: lake-tilting, a key to the discovery of Mesolithic sites in the interior of Northern Sweden. *Journal of Archaeological Science*, 30, 1451–1458.

- Bevan, D. (1987). *Forest Insects. A guide to insects feeding on trees in Britain*. Forestry Commission Handbook 1. H.M.S.O., London.
- Birks, H. H. and Birks, H. J. B. (2001). Future use of pollen analysis must include plant macrofossils. *Journal of Biogeography*, 27, 31-35.
- Birks, H. H., Lemdahl, G., Svendsen, J. I. and Landvik, J. Y. (1993). Palaeoecology of a late Allerød peat bed at Godøy, western Norway. *Journal of Quaternary Science*, 8, 147-159.
- Birks, H. J. B. (1981). The use of pollen analysis in the reconstruction of past climates: a review. In Wigley, T. M. L., Ingram, M. J. and Farmer, G. (eds.) *Climate and history. Studies in past climates and their impact of man*. University Press, Cambridge, 111-138.
- Björk, S. (1995). A review of the history of the Baltic Sea, 13.0 – 8.0 ka BP. *Quaternary International*, 27, 19-40.
- Björse, G. and Bradshaw, R. (1997). 2000 years of forest dynamics in southern Sweden: suggestions for forest management. *Forest Ecology and Management*, 104, 15-26.
- Bjune, A., Seppä, H. and Birks, H. J. B. (2009). Quantitative summer-temperature reconstructions for the last 2000 years based on pollen-stratigraphical data from northern Fennoscandia. *Journal of Paleolimnology*, 41 (1) 43-56.
- Blamey, M. and Grey-Wilson, C. (2003). *Wild Flowers of Britain and Northern Europe*. Cassell. London.
- Blaauw, M., van der Plicht, J., van Geel, B. (2004). Radiocarbon dating of bulk peat samples from raised bogs: non-existence of a previously reported ‘reservoir effect’? *Quaternary Science Reviews*, 23, 1537-1542.
- Blomqvist, M. (2007). *Informationssystemet för fornminnen – lista med lämningstyper och antikvarisk praxis (version 3.4)*. (Riksantikvarieämbetet. Kunskapsavdelning) Stockholm.
- Böcher, J. (1988). The Coleoptera of Greenland. Meddelelser om Grønland. *Biosciences*, 26.
- Böcher, J. (1995). Palaeoentomology of the Kap Kobenhavn Formation, a Plio-Pleistocene sequence in Peary Land, North Greenland. Meddelelser om Grønland. *Geoscience*, 33.



- Böcher, J. and Fredskild, B. (1993). Plant and arthropod remains from the Palaeo-Eskimo site at Qeqertasussuk, West Greenland. *Meddelelser om Grønland. Geoscience*, 30
- Böhme, J. (2005). *Die Käfer Mitteleuropas*. K. Katalog (Faunistische Übersicht) (2nd ed.). Spektrum Academic, Munich.
- Bondestam, K., Vasari, A., Vasari, Y., Lemdahl, G. and Eskonen, K. (1994). Younger Dryas and Preboreal in Salpausselkä Foreland, Finnish Karelia. *Dissertationes Botanicae*, 234, 161-206.
- Börgmark, A. (2005). Holocene climate variability and periodicities in south-central Sweden, as interpreted from peat humification analysis. *The Holocene*, 15 (3) 387-395.
- Bowstead, S. (1999). *A revision of the Corylophidae (Coleoptera) of the West Palaearctic region*. Muséum d'histoire naturelle Genève, Geneva.
- Bowman S. (1990). *Radiocarbon Dating*. British Museum Press, London.
- Bradley, M. J., Kutz, S. J., Jenkins, E. and O'Hara, T. M. (2005). The potential impact of climate change on infectious diseases of Arctic fauna. *International Journal of Circumpolar Health*, 64 (5) 468-477.
- Bradshaw, R. H. W. and Zachrisson, O. (1990). A Two Thousand Year History of a Northern Swedish Boreal Forest Stand. *Journal of Vegetation Science*, 1 (4) 519-528.
- Branigan, K., Edwards, K. J. and Merrony, C. (2002). Bronze Age fuel: the oldest direct evidence for deep peat cutting and stack construction? *Antiquity*, 76, 849-855.
- Bray, P. J. Blockley, S. P. E., Coope, G. R., Dadswekk, L. F., Elias, S. A., Lowe, J. J. and Pollard, A. M. (2006). Refining mutual climatic range (MCR) quantitative estimates of palaeotemperature using ubiquity analysis. *Quaternary Science Reviews*, 25, 1865-1876.
- Briffa, K. R. (2000). Annual climate variability in the Holocene: interpreting the message of ancient trees. *Quaternary Science Reviews*, 19 (1-5) 87-105.
- Briffa, K. R. and Matthews, J. A. (2002). ADVANCE-10K: a European contribution towards a hemispheric dendroclimatology for the Holocene. *The Holocene*, 12 (6) 639-642.

- Broadbent, N. (2010). *Lapps and Labyrinths: Saami Prehistory, Colonization and Cultural Resilience*. Arctic Studies Center/Smithsonian Institution, Washington, DC.
- Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon*, 51 (1) 337-360.
- Brundin, L. (1934). *Die Coleopteren des Tornetraskgebietes. Ein Beitrag zur Ökologie und Geschichte der Käferwelt in Schwedisch-Lappland*. Lund.
- Buckland, P. C. (1976). The use of insect remains in the interpretation of archaeological environments. In Davidson, D. A. and Shackley, M. L. (eds.) *Geoarchaeology: Earth Sciences and the Past*. Duckworth, London, 360-396.
- Buckland, P., Engelmark, R., Linderholm, J. and Wagner, P. (2001). Environmental archaeological investigation of samples from the Kaupang 2000 excavations. *Environmental Archaeology Lab. Report 2001-017*. Department of Archaeology and Sámi Studies, University of Umeå.
- Buckland, P. C., Panagiotakopulu, E., Buckland, P. I., Perdikaris, S. and Skidmore, P. (2006). Insect faunas from medieval Langenes in Arctic Norway. In Engelmark, R. and Linderholm, J. (eds.) *Proceedings from the 8th Nordic conference on the application of scientific methods in archaeology, Umeå 2001*. Department of Archaeology and Sámi Studies, University of Umeå, 17-32.
- Buckland, P. C., Perry, D. W. and Sveinbjarnardóttir, G. (1983). *Hydraena britteni* Joy (Coleoptera, Hydraenidae) fundin á Íslandi í setlögum frá því seint á nútíma. *Náttúrufræðingurinn*, 52, 37-44.
- Buckland, P. C. and Wagner, P. E. (2001). Is there an insect signal for the “Little Ice Age”? *Climatic Change*, 48, 137-149.
- Buckland, P. I. (2007). *The development and implementation of software for palaeoenvironmental and palaeoclimatological research: the Bugs Coleopteran Ecology Package (BugsCEP)*. Archaeology and Environment 23. Doctoral thesis, Environmental Archaeology Lab., Department of Archaeology and Sámi Studies, University of Umeå.
- Bullock, J. A. (1993). Host Plants of British Beetles: A List of Recorded Associations. *Amateur Entomologist*, 11a, 1-24.
- Butterfield, J. E. L. (1986). Changes in life-cycle strategies of *Carabus problematicus* over a range of altitudes in Northern England. *Ecological Entomology*, 11 (1) 17-26.

- Butterfield, J. E. L. (1996). Carabid life-cycle strategies and climate change: a study on an altitude transect. *Ecological Entomology*, 21, 9-16.
- Bylund, E. (1956). Koloniseringen av Pite lappmark t.o.m. år 1867. *Geographica*. Skrifter från Uppsala universitets Geografiska institutionen nr. 30.
- Campbell, J. M. (1982). A revision of the North American Omaliinae (Coleoptera: Staphylinidae). 3. The genus *Acidota* Stephens. *Canadian Entomologist*, 114, 1003-1029.
- Campbell, J. M. (1983). A revision of the North American Omaliinae (Coleoptera: Staphylinidae). The genus *Olophrum* Erichson. *Canadian Entomologist*, 115, 577-622.
- Campbell, J. M. (1984). A revision of the North American Omaliinae (Coleoptera: Staphylinidae). The genera *Arpedium* Erichson and *Eucnecosum* Reitter. *Canadian Entomologist*, 116, 487-527.
- Carpelan, C. and Hicks, S. (1995). Ancient Saami in Finnish Lapland and their impact on the forest vegetation. In Butlin, R. A. and Roberts, N. (eds.) *Ecological Relations in Historical Times*. Blackwell, 193-205.
- Carroll, A. L., Taylor, S. W., Régnière, J. and Safranyik, L. (2003). Effect of climate change on range expansion by the mountain pine beetle in British Columbia. *Mountain Pine Beetle Symposium: Challenges and Solutions*. October 30-31, 2003, Kelowna, British Columbia.
- Carrott, J. and Kenward, H. K., (2001). Species associations among insect remains from urban archaeological deposits and their significance in reconstructing the past human environment. *Journal of Archaeological Science*, 28, 887-905.
- Charman, D. (2002). *Peatlands and Environmental Change*. Wiley and Sons, Chichester.
- Charman, D. J., Aravena, R. and Warner, B. G. (1994). Carbon dynamics in a forested peatland in north-eastern Ontario, Canada. *Journal of Ecology*, 82, 55-62.
- Church, M. J., Arge, S. V., Brewington, S., McGovern, T. H., Woollett, J. W., Perdikaris, S., Lawson, I. T., Amundsen, C., Harrison, R., and Krivogorskaya, K. (2005). Puffins, Pigs, Cod, and Barley: Palaeoeconomy at Undir Junkarinsflótti, Sandoy, Faroe Islands. *Environmental Archaeology*, 10, 179-197.
- Coope, G. R. (1975). Climatic fluctuations in northwest Europe since the Last Interglacial, indicated by fossil assemblages of Coleoptera. In Wright, A. E. and

Moseley, F. (eds.) *Ice Ages: Ancient and Modern*. Geological Journal Special Issue 6. Seel House Press, Liverpool, 153-168.

Coope, G. R. (1977). Fossil Coleopteran assemblages as sensitive indicators of climatic changes during the Devensian (Last) cold stage. *Philosophical Transactions of the Royal Society of London*, B280, 313-337.

Coope, G. R. (1978). Constancy of insect species versus inconstancy of Quaternary environments. In Mound, L. A. and Waloff, N. (eds.) *Diversity of Insect Faunas*. Blackwell Science Publications, Oxford, 176-187.

Coope, G. R. (1986). Coleoptera analysis. In Berglund, B. E. (ed.) *Handbook of Holocene Palaeoecology and Palaeohydrology*. J. Wiley and Sons, Chichester, 703-713.

Coope, G. R. (2004). Rapid climatic change – what can we learn from history? *ESS Bulletin*, 2, 8-10.

Coope, G. R. and Brophy, J. A. (1972). Late Glacial environmental changes indicated by a Coleopteran succession from North Wales. *Boreas*, 1, 97-142.

Coope, G. R. and Böcher, J. (2000). Coleoptera from the Late Weichselian deposits at Nørre Lyngby, Denmark and their bearing on palaeoecology, biogeography and palaeoclimate. *Boreas*, 29, 26-34.

Coope, G. R. and Lemdahl, G. (1996). Validations for the use of beetle remains as reliable indicators of Quaternary climates: a reply to the criticisms by Johan Andersen. *Journal of Biogeography*, 23 (1) 115-20.

Coope, G. R., Lemdahl, G., Lowe, J.J. and Walking, A. (1998). Temperature gradients in northern Europe during the last glacial–Holocene transition (14–9 <sup>14</sup>C kyr BP) interpreted from Coleopteran assemblages. *Journal of Quaternary Science*, 13, 419-433.

Coope, G. R. and Osbourne, P. J. (1968). Report on the Coleopterous fauna of the Roman well at Barnsley Park, Gloucestershire. *Transactions of the Bristol and Gloucestershire Archaeological Society*, 86, 84-87.

Coope, G. R., Shotton, F. W. and Strachan, I. (1961). A Late Pleistocene fauna and flora from Upton Warren, Worcestershire. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, 379-421.

Coulson, J., Bauer, J., Butterfield, I., Downie, I., Canna, L. and Smith, C. (1995). The invertebrates of the Northern Scottish Flows, and a comparison with other peatland

- habitats. In Thompson, D. B. A., Hester, A. J. and Usher, M. B. (eds.) *Heather and Moorlands: Cultural landscapes*. HMSO, Edinburgh.
- Cowling, S. A., Sykes, M. T. and Bradshaw, R. H. W. (2001). Palaeovegetation-model comparisons, climate change and tree succession in Scandinavia over the past 1500 years. *Journal of Ecology*, 89 (2) 227-236.
- Cuppen, J. G. M. and Nilsson, A. (1991). Ochthebius rugulosus Wollaston in Fennoscandia (Coleoptera, Hydraenidae). *Entomologisk Tidskrift*, 112, 39-42.
- Dahl, E. (1998). *The Phytogeography of Northern Europe: British Isles, Fennoscandia, and Adjacent Areas*. Cambridge University Press.
- Dahlström, B. (1995). Snow Cover. In Raab, B. and Vedin, H. (eds.) *Climate, Lakes and Rivers*. National Atlas of Sweden, SNA Publishing, 91-97.
- Davidyan, G. E. (2008) Pests. *Chaetocnema aridula* Gyll., *Chaetocnema hortensis* Geoffr. - Cereal stem flea beetles. In Afonin, A. N, Greene, S. L., Dzyubenko, N. I. and Frolov, A. N. (eds.) *Interactive Agricultural Ecological Atlas of Russia and Neighboring Countries. Economic Plants and their Diseases, Pests and Weeds* [Online]. Available at: <http://www.agroatlas.ru>.
- den Boer, P. J. (1977). Dispersal Power and Survival. Carabids in a cultivated countryside. *Misc. Papers LH Wageningen*, 14, 1-190.
- Dinnin, M. (1997). Holocene beetle assemblages from the. Lower Trent floodplain at Bole Ings, Nottinghamshire, UK. In Ashworth, A. C., Buckland, P. C. and Sadler, J. P. (eds.) *Studies in Quaternary entomology: an inordinate fondness for insects. Quaternary Proceedings*, 5, 293-303.
- Doguet, S. (1994). Coléoptères Chrysomelidae, Volume 2 Alticinae. *Faune de France*, 80 (2).
- Donisthorpe, H.St.J.K. (1939). *A Preliminary list of the Coleoptera of Windsor Forest*. Lloyd and Co., London.
- Duff, A. (1993). *Beetles of Somerset: their status and distribution*. Somerset Archaeological and Natural History Society, Taunto.
- Dugmore, A. J., Church, M. J., Buckland, P. C., Edwards, K. J., Lawson, I., McGovern, T. H, Panagiotakopulu, E., Simpson, I. A, Skidmore, P. and Sveinbjarnardóttir, G. (2005). The Norse *landnám* on the North Atlantic islands: an environmental impact assessment. *Polar Record*, 41, 21-37.

- Ehnström, B. (2001). Leaving dead wood for insects in boreal forests – suggestions for the future. *Scandinavian Journal of Forest Research*, 16, supplement 3, 91-98.
- Eidmann, H. H. (1992). Impact of bark beetles on forests and forestry in Sweden. *Journal of Applied Entomology*, 114, 193–200.
- Eide, W. and Aronsson, M. (2010). Fjällen. The Swedish Mountains. In Gärdenfors, U. (ed.) *Rödlistade arter i Sverige 2010. The 2010 Red List of Swedish Species*. ArtDatabanken SLU, Uppsala, 106-112.
- Ekman, J. and Iregren, E. (1983). Archaeo-zoological investigations in northern Sweden. *Early Norrland*, 8, 1-99.
- Elias, S. A. (2007). Overview of Fossil Beetles. In Elias, S. A. (ed.) *Encyclopedia of Quaternary Science*. Vol. 1 Elsevier Science Publishers B.V. (North-Holland), 153-163.
- Elias, S. A. (2010). *Advances in Quaternary Entomology. Developments in Quaternary Science*, 12. Elsevier, Amsterdam.
- Elias, S. A., Anderson, K. and Andrews, J. T. (1996). Late Wisconsin climate in the northeastern United States and southeastern Canada, reconstructed from beetle assemblages, *Journal of Quaternary Science*, 11, 417-421.
- Emanuelsson, M. and Segerström, U. (2002). Medieval Slash-and-Burn Cultivation: Strategic or Adapted Land Use in the Swedish Mining District? *Environment and History*, 8, 173–96.
- Engelmark, R. (1976). The vegetational history of the Umeå area during the past 4000 years. *Early Norrland*, 9, 75-111.
- Engelmark, R. (1978). The comparative vegetational history of inland and coastal sites in Medelpad, N Sweden, during the Iron Age. *Early Norrland*, 11, 25-62.
- Engelmark, R. (1979). The paleoenvironment. In Broadbent, N. (ed.) *Coastal Resources and Settlement Stability. A critical study of a mesolithic site complex in northern Sweden*. AUN 3, Institute of North European Archaeology, Uppsala, 165-166.
- Engelmark, R. (1996). North Sweden. In Berglund, B. E., Birks H. J. B. and Ralska-Jasiewiczowa, M. (eds.) *Palaeoecological events during the last 15000 years: regional syntheses of palaeoecological studies of lakes and mires in Europe*. Wiley, Chichester, 266-276.

- Eronen, M. (2005). Land uplift: virgin land from the sea. In Seppälä, M. (ed.) *The Physical Geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 17-34.
- Eronen, M., Zetterberg, P., Briffa, K. R., Lindholm, M., Meriläinen, J. and Timonen, M. (2002). The supra-long Scots pine tree-ring record for Finnish Lapland: Part 1, chronology construction and initial inferences. *The Holocene*, 12 (6) 673-680.
- Esseen, P.-A., Ehnström, B., Ericson, L. and Sjöberg, K. (1997). Boreal Forests. *Ecological Bulletins*, No. 46, Boreal ecosystems and landscapes: structures, processes and conservation of biodiversity, 16-47.
- Eurola, S., Huttunen, A. and Kukko-oja, K. (1995). Suokasvillisuusopas [Mire vegetation guide] Oulanka Reports 14, 1–85.
- Eyre, M. D. and Luff, M. L. (1990). The Ground Beetle (Coleoptera: Carabidae) Assemblages of British Grasslands. *Entomologist's Gazette*, 41, 197-208.
- Fedorenko, D. N. (1997). *Reclassification of world Dyschiriini, with a revision of the Palaearctic fauna* (Coleoptera, Carabidae). Pensoft, Sofia.
- Ferrar, P. (1987). A guide to the breeding habits and immature stages of Diptera Cyclorrhapha. *Entomonograph*, 8, 1–907.
- Ferreira, L. and Hitchcock, D. B. (2009). A Comparison of hierarchical methods for clustering functional data. *Communications in statistics: simulation and Computation*, 38, 1925-1949.
- Fisher, R. A., Corbet, S. A. and Williams, C. B. (1943). The relation between the number of species and the number of individuals in a random sample of an animal population. *Journal of Animal Ecology*, 12, 42–57.
- Flint, A. (2010). *Reindeer herding as a high-level buffering mechanism : the role of climate change in a multi-causal model of the emergence of reindeer herding among the Sami of northern Sweden*. Doctoral thesis, The University of Sheffield.
- Flint, J. H. (1963). Coleoptera. In The Insects of the Malham Tarn Area. *Proceedings of the Leeds Philosophical and Literary Society*, Scientific Section, 9, 45-56.
- FOET Report (2011). *Footsteps on the edge of Thule – Landscapes of Norse-indigenous interaction*. Final Report (2007-2011). The Leverhulme Trust: Programme Grant F/00 152/Q.

- Folstad, I., Nilssen, A. C., Halvorsen, O. and Andersen, J. (1991). Parasite avoidance: the cause of post-calving migrations in *Rangifer*? *Canadian Journal of Zoology*, 69 (9) 2423-2429.
- Folwaczny, B. (1983). Cossoninae. In Freude, H., Harde, K.W. and Lohse, G.A. (eds.) *Die Käfer Mitteleuropas*, 11, 30-43. Goecke and Evers, Krefeld.
- Forsberg, L. (1985). Site variability and settlement patterns. An analysis of the hunter-gatherer settlement system in the Lule River valley, 1500 B.C.-B.C./A.D. *Archaeology and Environment* 3. Department of Archaeology, University of Umeå.
- Forsythe, T. G. (1982). Feeding mechanisms of certain ground beetles (Coleoptera: Carabidae). *Coleopterists Bulletin*, 36, 26-73.
- Foster, G. (2000). *A review of the scarce and threatened Coleoptera of Great Britain. Part 3. Water Beetles*. UK Joint Nature Conservation Committee, Peterborough.
- Foster, G. N. and Friday, L. E. (2011). *Keys to the adults of the water beetles of Britain and Ireland (Part 1). Handbooks for the Identification of British insects* 4 (5). Royal Entomological Society and Field Studies Council.
- Fredén, C. (1994). Quaternary deposits. In Fredén, C. (ed). *Geology*. National Atlas of Sweden, SNA Publishing, 104-119.
- Freléchoux, F., Buttler, A., Schweingruber, F. H. and Gobat, J. M. (2000). Stand structure, invasion, and growth dynamics of bog pine (*Pinus uncinata* var. *rotundata*) in relation to peat cutting and drainage in the Jura Mountains, Switzerland. *Canadian Journal of Forest Research*, 30, 1114-1126.
- Freude, H., Harde, K. W. and Lohse, G. A. (1964). *Die Käfer Mitteleuropas*. Band 4. Staphylinidae I. Goecke and Evers, Krefeld
- Freude, H., Harde, K. W. and Lohse, G. A. (1981). *Die Käfer Mitteleuropas*. Band 10. Goecke and Evers, Krefeld
- Friday, L. E. (1988). A key to the adults of British water beetles. *Field Studies*, 7, 1-151.
- Gaillard, M-J. and Lemdahl, G. (1994). Early Holocene coastal environments and climate in southeast Sweden: a reconstruction based on macrofossils from submarine deposits. *The Holocene*, 4, 53-68.
- Gaillard, M-J., Lemdahl, G., Greisman, A., Olsson, F., Skoglund, P. (2009). The role of climate, human impacts and fire on forest dynamics, landscape development and biodiversity during the last 10,500 calendar years in southern Sweden – a



- synthesis of the multiproxy study of Stavsåkra bog. In Olsson, F. *Structures and Disturbances in Holocene forests of southern Sweden – interpreted from insect and charcoal studies*. Doctoral thesis, School of Pure and Applied Natural Sciences, University of Kalmar, series no. 67.
- García, D., Zamora, R., Gómez, J. M., Jordano, P. and Hódar, J. A. (2000). Geographical variation in seed production, predation and abortion in *Juniperus communis* throughout its range in Europe. *Journal of Ecology*, 88, 436-446.
- Gardner, J.J. and Whitlock, C. (2001). Charcoal accumulation following a recent fire in the Cascade Range, northwestern USA, and its relevance for fire-history studies. *The Holocene*, 11(5) 541-549.
- Gärdenfors, U. (ed.) (2010). Rödlistade arter i Sverige 2010. The 2010 Red List of Swedish Species. ArtDatabanken SLU, Uppsala.
- Garland, S. (1983). Beetles as primary woodland indicators. *The Sorby Record*, 21, 3-38.
- Gaston, K. J. and Williams, P. H. (1996). Spatial patterns in taxonomic diversity. In Gaston, K. J. (ed.) *Biodiversity: a biology of numbers and difference*. Oxford, U.K. Blackwell Science Ltd, 202-229.
- Gerell, R., Guasstafsson, L., Ingelög, T., Johansson, O., Lindberg, P. S., Linder, P., Löfroth, M., Pålsson, L., Rafstedt, T., Rosén, E. (1996). Ecosystems. In Gustafsson and Ahlén, I. (eds.) *Geography of plants and animals*. National Atlas of Sweden, SNA Publishing, 39-65.
- Gittings, T. and Giller, P. S. (1997). Life history traits and resource utilisation in an assemblage of north temperate Aphodius dung beetles. *Ecography*, 20, 55-66.
- Gønget, H. (1997). The Brentidae (Coleoptera) of Northern Europe. *Fauna Entomologica Scandinavica* 34. Brill, Leiden.
- Goslar, T., van der Knaap, W. O., Hicks, S., Andrič, M., Czernik, J., Goslar, E., Räsänen, S. and Hyötylä, H. (2005). Radiocarbon dating of modern peat profile: Pre- and post-bomb <sup>14</sup>C Variations in the construction of age-depth models. *Radiocarbon*, 47 (1) 115-134.
- Göthlin, E., Schroeder, L. M. and Lindelöw, A. (2000). Attacks by *Ips typographus* and *Pityogenes chalcographus* on Windthrown Spruces (*Picea abies*) During the Two Years Following a Storm Felling. *Scandinavian Journal of Forest Research*, 15 (5) 542-549.

- Granlund, E. (1932). *De svenska högmossarnas geologi*. Stockholm: Sveriges Geologiska Undersökning Series C, 373.
- Granlund, E. (1943). Beskrivning till jordartskarta över Västerbottens län nedanför odlingsgränsen [Description of the map of the Quaternary deposits of the Eastern and Central parts of the Västerbotten County.] *Sveriges Geologiska Undersökning Ca*, 1-65.
- Greisman, A. and Gaillard, M-J. (2009). The role of climate variability and fire in early and Mid-Holocene forest dynamics of southern Sweden. *Journal of Quaternary Science*, 24 (6) 593–611.
- Grove, S. J. (2002). Saproxylic insect ecology and the sustainable management of forests. *Annual Review of Ecology and Systematics*, 33 (1) 1-23.
- Grudd, H. (2008). Torneträsk tree-ring width and density AD 500-2004: a test of climatic sensitivity and a new 1500-year reconstruction of north Fennoscandian summers. *Climate Dynamics*, 31 (7-8) 843-857.
- Grudd, H., Briffa, K. R., Karlén, W., Bartholin, T. S., Jones, P. D. and Kromer, B. (2002). A 7400-year tree-ring chronology in northern Swedish Lapland: natural climatic variability expressed on annual to millennial timescales. *The Holocene*, 12 (6) 657-665.
- Gunnarson, B. E., Josefsson, T., Linderholm H. W., Östlund, L., (2012). Can legacies of pre-industrial land use bias modern tree-ring climate calibrations? *Climate Research*, 53, 63-76.
- Gustafsson, B. (2005). (CATCOL2004.XLS) revised 2005-02-01 Bert Gustafsson NRM. Original title *Catalogus Coleopterorum Sueciae* 1995.
- Gustavsson, G. (2009). Insect Remains from a Late Medieval Well. In Gustavsson, G. *Late Holocene forest history in south-western Sweden – with emphasis on grazing in forest ecosystems*. Doctoral thesis, School of Pure and Applied Natural Sciences, University of Kalmar, Sweden.
- Gustavsson, G., Lemdahl, G. and Gaillard, M-J. (2009a). Abrupt forest ecosystem change in SW Sweden during the late Holocene. *The Holocene*, 19 (5) 691-702.
- Gustavsson, G., Lemdahl, G. and Olsson, F. (2009b). Beetle remains as indicators for grazing and openness in ancient landscapes – evaluations by surface sample studies. In Gustavsson, G. *Late Holocene forest history in south-western Sweden – with emphasis on grazing in forest ecosystems*. Doctoral thesis, School of Pure and Applied Natural Sciences, University of Kalmar.

- Hadwen, S. (1926). Notes on the Life History of *Oedemagena tarandi* L. and *Cephenomyia trompe* Modeer. *The Journal of Parastiology*, 13 (1) 56-65.
- Hammer, Ø. (2009). *PAST PAleontological STatistics*, Version 1.94b Reference manual. University of Oslo.
- Hammer, Ø. (2011). *Ecological cluster analysis with Past*. Natural History Museum, University of Oslo.
- Hammer, Ø. and Harper, D. (2006). *Paleontological Data Analysis*. Blackwell Publishing, Oxford.
- Hammer, Ø., Harper, D.A.T. and Ryan, P. D. (2001). PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica*, 4 (1) 1-9.
- Hansen, M. (1987). The Hydrophiloidea (Coleoptera) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica*, 18. Scandinavian Science Press, Leiden.
- Hanski, I. (1980). Spatial variation in the timing of the seasonal occurrence in coprophagous beetles. *OIKOS*, 34, 311-321.
- Hanski, I. (1991). North temperate dung beetles. In Hanski, I. and Cambefort, Y. (eds.) *Dung Beetle Ecology*. Princeton University Press, Princeton, New Jersey, 75-96.
- Hanski, I. and Cambefort, Y. (1991). Species richness. In Hanski, I. and Cambefort, Y. (eds.) *Dung Beetle Ecology*. Princeton University Press, Princeton, New Jersey, 350-365.
- Hanski, I. and Cambefort, Y. (1991b). Dung Beetle Population Biology. In Hanski, I. and Cambefort, Y. (eds.) *Dung Beetle Ecology*. Princeton University Press, Princeton, New Jersey, 36-50.
- Harde, K. W. (1984). *A Field Guide in Colour to Beetles*. Octopus, London.
- Hedman, S.-D. (2003). *Boplatser och offerplatser. Ekonomisk strategi och boplatster bland skogssamer 700-1600 AD*. Studia Archaeologica Universitatis Umensis 17. Doctoral thesis, Department of Archaeology and Saami Studies, University of Umeå.
- Hellberg, E. (2004). *Historical variability of deciduous trees and deciduous forests in northern Sweden. Effects of forest fires, land use and climate*. Acta Universitatis Agriculturae Sueciae Silvestria 308. Doctoral thesis, Swedish University of Agricultural Sciences, Umeå.

- Helmfrid, S. and Östman, P. (1996). Geography. In Helmfrid, S (ed.) *The Geography of Sweden*. National Atlas of Sweden, SNA Publishing, 6-13.
- Helle, M., Sonstegaard, E., Coope, G. R. and Rye, N. (1981). Early Weichselian peat at Brumunddal, southeastern Norway. *Boreas*, 10, 369-379.
- Hellqvist, M. (1999a). *Urban and rural environments from Iron Age to medieval time in Northern Europe. Evidence from insect remains from South-Eastern Sweden and Novgorod, Russia*. Acta Universitatis Upsaliensis. Doctoral thesis, School of Technology and Business Studies, Dalarna University.
- Hellqvist, M. (1999b). Insect Assemblages from Iron Age wells in central Sweden. *Norwegian Archaeological Review*, 32 (1) 1-17.
- Hellqvist, M. and Lemdahl, G. (1996). Insect assemblages and local environment in the mediaeval town of Uppsala, Sweden. *Journal of Archaeological Science*, 23, 873-881.
- Hellström P. (1917). *Norrlands jordbruk*. Uppsala.
- Henriksen, K. L. (1914). Die Spät-Glaciales und Alluviale Insekten-Fauna des Moores Femsölyng in Nordseeland (Danemark). *Meddelelser fra Dansk geologisk Forening*, 4, 271-286.
- Henriksen, K. L. (1933). Undersøgelser over Danmark-Skånes kvartære Insektfauna. *Videnskabelige Meddelelser fra Dansk naturhistorisk Forening*, 96, 77-355.
- Hickin, N. E. (1968). *The Insect Factor in Wood Decay* (2nd ed.). Hutchinson, London.
- Hicks, S. (1976). Pollen analysis and archaeology in Kuusamo, north-east Finland, an area of marginal human interference. *Transactions of the Institute of British Geographers*, New Series, 1 (3) 362-384.
- Hicks, S. (1988). The representation of different farming practices in pollen diagrams from northern Finland. In Birks, H. H., Birks, H. J. B., Kaland, P. E. and Moe, D. (eds.) *The Cultural landscape - Past, Present and Future*. Cambridge University Press, 189-207.
- Hicks, S. (1993). Pollen evidence of localized impact on the vegetation of northernmost Finland by hunter-gatherers. *Vegetation History and Archaeobotany*, 2 (3) 137-144.
- Hicks, S. (1995). The history of a wilderness area of Finnish Lapland as revealed by pollen analysis. *Arctic Centre Publications*, 7, 126-140.

- Hicks, S. (2006). When no pollen does not mean no trees. *Vegetation History and Archaeobotany*, 14 (4) 253-261.
- Hicks, S. and Birks, H. J. B. (1996). Numerical analysis of modern and fossil pollen spectra as a tool for elucidating the nature of fine-scale human activities in boreal areas. *Vegetation History and Archaeobotany*, 5, 257-272.
- Higuera, P. E., Sprugel, D. G. and Brubaker, L. B. (2005). Reconstructing fire regimes with charcoal from small-hollow sediments: a calibration with tree-ring records of fire. *The Holocene*, 15 (2) 238-251.
- Hill, M. O. and Gauch, H. G. (1980). Detrended Correspondence Analysis: an improved ordination technique. *Vegetatio*, 42, 47-58.
- Hjelle, K.L., Halvorsen, L.S. and Overland, A. (2010). Heathland development and relationship between humans and environment along the coast of western Norway through time. *Quaternary International*, 220 (1-2) 133-146.
- Hoffmann, A. (1954). *Coleoptères Curculionides 2*. Faune de France, 59, 487-1208. Lechevalier, Paris.
- Hoffmann, A. (1958). *Coleoptères Curculionides 3*. Faune de France, 62. Paris.
- Holm, L. (1992). The use of stone and hunting of reindeer. *Archaeology and Environment* 12. University of Umeå.
- Horion, A. (1953). *Faunistik der Mitteleuropäischen Käfer*, 3. Malacodermata, Sternoxia (Elateridae - Throscidae). G. Frey, Munich.
- Horion, A. (1955). *Faunistik der Mitteleuropäischen Käfer* 4. Sternoxia (Buprestidae), Fossipedes, Macroductylia, Brachymera. G. Frey, Munich.
- Hörnberg, G., Bohlin, E., Hellberg, E., Bergman, I., Zackrisson, O., Olofsson, A., Wallin, J-E., Pässe, T. (2005). Effects of Mesolithic hunter-gatherers on local vegetation in a non-uniform glacio-isostatic land uplift area, northern Sweden. *Vegetation History and Archaeobotany*, 15 (1) 13-26.
- Hörnberg, G., Östlund, L., Zackrisson, O. and Bergman, I. (1999). The genesis of two Picea-Cladina forests in northern Sweden. *Journal of Ecology*, 87 (5) 800-814.
- Huggert, A. (2000). A church at Lycksele and a sacrificial site on Altaberget - the two worlds of the Saami. *Acta Borealia*, 17 (1) 51-76.

- Hultblad, F. (1968). Övergång från nomadism till agrar bosättning i Jokkmokks socken [Transition from nomadism to farming in the parish of Jokkmokk]. *Acta Lapponica* 14. Stockholm, Almqvist and Wiksell/Gebers.
- Hunter, F. A. (1977). Ecology of Pinewood beetles. In Bunce, R. G. H. and Jeffers, J. N. R. (eds.) *Native Pinewoods of Scotland*, 42-55. Institute of Terrestrial Ecology, Cambridge.
- Hyman, P. S. (1992). *A review of the scarce and threatened Coleoptera of Great Britain*, Part 1 (Revised and updated by M.S.Parsons). UK Joint Nature Conservation Committee, Peterborough.
- Hyman, P.S. (1994). *A review of the scarce and threatened Coleoptera of Great Britain*. Part 2. (Revised and updated by M.S. Parsons). UK Joint Nature Conservation Committee, Peterborough.
- Hynynen, J., Niemistö, P., Viherä-aarnio, A., Brunner, A., Hein, S., and Velling, P. (2010). Silviculture of birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) in northern Europe. *Forestry* 83 (1) 103-119.
- Hyvärinen, H. and Alhonen, P. (1994). Holocene lake-level changes in the Fennoscandian tree-line region, western Finnish Lapland: diatom and cladoceran evidence. *The Holocene*, 4 (3) 251-258.
- Hyvärinen, V. and Kajander, J. (2005). Rivers and lakes of Fennoscandia. In Seppälä, M. (ed.) *The Physical Geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 135-158.
- Inga, B. (2007). Reindeer (*Rangifer tarandus tarandus*) feeding on lichens and mushrooms; traditional ecological knowledge among reindeer-herding Sámi in northern Sweden. *Rangifer*, 27, 93-106
- Iver, R. Hagemoen, M. and Reimers, E. (2002). Reindeer summer activity pattern in relation to weather and insect harassment. *Journal of Animal Ecology*, 71 (5) 883-892.
- Jessop, L. (1986). Coleoptera: Scarabaeidae. *Handbooks for the Identification of British Insects*, 5 (11). Royal Entomological Society of London.
- Johansson, C. E. (2005). Rivers Draining into the Gulf of Bothnia. In Seppälä, M. (ed.) *The Physical Geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 325-348.
- Jonasson, C. (1996). The Land. In Helmfrid, S. (ed.) *The Geography of Sweden*. National Atlas of Sweden, SNA Publishing, 16-41.

- Johnson, C. (1992). Familie Cryptophagidae. In Lohse, G. A. and Lucht, W. H. (eds.) *Die Käfer Mitteleuropas 2. Supplementband mit Katalogteil*, 114-136. Goecke and Evers, Krefeld.
- Johnson, C. (1993). *Provisional Atlas of the Cryptophagidae - Atomariinae* (Coleoptera) of Britain and Ireland. Biological Records Centre, Huntingdon.
- Jonsell, M., Weslian, J. and Ehnström, B. (1998). Substrate requirements of red-listed saproxylic invertebrates in Sweden. *Biodiversity and Conservation*, 7, 749-764.
- Jönsson, A. M., Appelberg, G., Harding, S. and Barring, L. (2008). Spatio-temporal impact of climate change on the activity and voltinism of the spruce bark beetle, *Ips typographus*. *Global Change Biology*, 15 (2) 486-499.
- Josefsson, T. (2009). *Pristine forest landscapes as ecological references: Human land use and ecosystem change in boreal Fennoscandia*. Acta Universitatis agriculturae Sueciae 77. Doctoral thesis, Department of Forest Ecology and Management, University of Umeå.
- Josefsson, T., Hörnberg, G., and Östlund, L. (2009). Long-term human impact and vegetation changes in a boreal forest reserve: implications for the use of protected areas as ecological references. *Ecosystems*, 12 (6) 1017–1036. doi:10.1007/s10021-009-9276-y.
- Josefsson, T., Bergman, I. and Östlund (2010a). Quantifying Sámi Settlement and Movement Patterns in Northern Sweden 1700–1900. *Arctic*, 63 (2) 141-154.
- Josefsson, T., Gunnarson, B., Liedgren, L., Bergman, I. and Ostlund, L. (2010b). Historical human influence on forest composition and structure in boreal Fennoscandia. *Canadian Journal of Forest research*, 40, 872-884.
- Joy, N. H. (1976). *A Practical Handbook of British Beetles*. EW Classey Ltd, Faringdon, U.K.
- Kaland, P. E. (1986). The origin and management of Norwegian coastal heaths as reflected by pollen analysis. In Behre K. E. (ed.) *Anthropogenic Indicators in Pollen Diagrams* (Rotterdam: Balkema), 19-36.
- Karlén, W. (1976). Lacustrine sediments and tree-limit variations as indicators of Holocene climatic fluctuations in Lappland, Northern Sweden. *Geografiska Annaler*, 58A, 1-34.

- Karlsson, H., Hörnberg, G., Hannon, G., Nordström, E.-M. (2007). Long-term vegetation changes in the northern Scandinavian forest limit: a human impact-climate synergy? *The Holocene*, 17, 37-49
- Karlsson, N. (2006). *Bosättning och resursutnyttjande: miljöarkeologiska studier av boplatser med härdar från perioden 600-1900 e. Kr inom skogsSámskt område [Settlement and subsistence: environmental archaeological studies of dwelling sites with hearths from the period 600-1900 AD in forest Sámi area]*. Studia archaeologica Universitatis Umensis 21. Doctoral thesis, Department of Archaeology and Sámi Studies, University of Umeå.
- Kempe, G. and von Segebaden, G., (1990). What do the forests look like? In Nilsson, N. E. (ed.) *The Forests*. National Atlas of Sweden, SNA Publishing, 56–69.
- Kenward, H. K. (1975). Pitfalls in the environmental interpretation of insect death assemblages. *Journal of Archaeological Science*, 2, 85-94.
- Kenward, H. K. (1978). *The Analysis of Archaeological Insect Assemblages: a New Approach*. Archaeology of York, 19/1. Council for British Archaeology for York Archaeological Trust.
- Kenward, H. K. (1985). Outdoor-indoors? The outdoor component of archaeological insect assemblages. In Fieller, N. R. J., Gilbertson, D. D. and Ralph, N. G. A. (eds.) *Palaebiological Investigation: Research Design, Methods and Data Analysis*, 97-104.
- Kenward, H. K. (2002). *Assessment of insects and other invertebrate remains from Viborg Søndersø, Denmark*. Reports from the Environmental Archaeology Unit, York, 2002/14.
- Kenward, H. (2006). The visibility of past trees and woodland: testing the value of insect remains. *Journal of Archaeological Science*, 33, 1368-1380.
- Kenward, H. K. and Large, F. (1998). Recording the preservational condition of archaeological insect fossils. *Environmental Archaeology*, 2, 49-60.
- Kilian, M. R., van der Plicht, J. and van Geel, B. (1995). Dating raised bogs: new aspects of AMS  $^{14}\text{C}$  wiggle matching, a reservoir effect and climatic change. *Quaternary Science Reviews*, 14, 959–966.
- Kitti, H., Gunsley, N. and B. C. Forbes (2006). Defining the quality of reindeer pastures: the perspectives of Sámi reindeer herders. In Forbes, B. C. Bölter, M., Müller-Wille, L., Hukkinen, J., Müller, F., Gunsley, N. and Kontatinov, Y. (eds.) *Reindeer*



- management in northernmost Europe: linking practical and scientific knowledge in social-ecological systems. *Ecological Studies*, 184, 141-165.
- Kitti, H., Forbes, B. and Okansen, J. (2009). Long and short-term effects of reindeer grazing on tundra wetland vegetation. *Polar Biology*, 32, 253-261.
- Kjellström, R. (1983). *Lappmarksmikroskop. Intensivinventering av kulturlämningar i Jokkmokksfjällen*. Nordiska Museet. Stockholm.
- Koch, K. (1989a). Die Käfer Mitteleuropas. *Ökologie*, 1. Goecke and Evers, Krefeld.
- Koch, K. (1989b). Die Käfer Mitteleuropas, *Ökologie* 2. Goecke and Evers, Krefeld.
- Koch, K. (1992). Die Käfer Mitteleuropas. *Ökologie* 3. Goecke and Evers, Krefeld.
- Koivula, M., Hyyrylainen, V., and Soininen, E. (2004). Carabid beetles (Coleoptera: Carabidae) at forest-farmland edges in southern Finland. *Journal of Insect Conservation*, 8 (4) 297-309.
- Kokfelt, U., Reuss, N., Struyf, E., Sonesson, M., Rundgren, M., Skog, G., Rosén, P. and Hammarlund, D. (2010). Wetland development, permafrost history and nutrient cycling inferred from late Holocene peat and lake sediment records in subarctic Sweden. *Journal of Paleolimnology*, 44 (1) 327-342.
- Kolstrup, E. (2007). Water-borne macroscopic plant particle transport through central and northern Europe during warming phases: a hypothetical spreading mechanism for climatic pioneers. *GFF*, 129 (4) 307-313.
- Koponen, M. and Nuorteva, M. (1973). Über subfossile Waldinsekten aus dem Moor Piilonsuo in Südfinnland. *Acta Entomologica Fennica*, 29, 1-84.
- Korhola, A. (1995). Holocene climatic variations in southern Finland reconstructed from peat-initiation data. *The Holocene*, 5, 43-58.
- Korhola, A., Weckström, J., Holmström, L. and Erästö, P. (2000). A quantitative Holocene climatic record from diatoms in northern Fennoscandia. *Quaternary Research*, 54, 284-294.
- Korsman, T. and Segerström, U. (1998). Forest fire and lake-water acidity in a northern Swedish boreal area: Holocene changes in lake-water quality at Makkassjön. *Journal of Ecology*, 86, 113-124.
- Krebs, C. J. (1999). *Ecological Methodology*. Benjamin/Cummings, Mento Park.

- Krell, F.-T., Johnson, C., Booth, R. & Mendel, H. (2005). The British *Dienerella separanda* (Reitter) is *D. clathrata* (Mannerheim): with a compilation of British records of *D. clathrata* and *D. elongata* (Curtis) (Latridiidae). *The Coleopterist*, 14, 117-123.
- Kroll, H. (1990). Melde von Feudvar, Vojvodina. *Praehistorische Zeitschrift*, 65, 46–48.
- Krupnik, I. (1993). *Arctic adaptations: native whalers and reindeer herders of northern Eurasia*. University Press of New England, Hanover.
- Kullman, L. (1995) Tree-Limit and Climate History from the Scandes Mountains, Sweden. *Ecology*, 76 (8) 2490 -2502.
- Kullman, L. (1998a). Non-analogous tree flora in the Scandes Mountains, Sweden, during the early Holocene - macrofossil evidence of rapid geographic spread and response to palaeoclimate. *Boreas*, 27 (3) 153-161.
- Kullman, L. (1998b). The occurrence of thermophilous trees in the scandes Mountains during the early Holocene: evidence for diverse tree flora and from macroscopic remains. *Journal of Ecology*, 86, 421-428.
- Kullman, L. (1999). Early Holocene tree growth at a high elevation site in the northernmost Scandes of Sweden (Lapland): A palaeobiogeographical case study based on megafossil evidence. *Geografiska Annaler*, 81 A (1) 63-74.
- Kullman, L. (2000). The geoecological history of *Picea abies* in northern Sweden and adjacent parts of Norway. A contrarian hypothesis of postglacial tree immigration patterns. *GeoÖko*, 21, 141-172.
- Kullman, L. (2001). Immigration of *Picea abies* into North-Central Sweden. New evidence of regional expansion and tree-limit evolution. *Nordic Journal of Botany*, 21, 39-54.
- Kullman, L. (2002). Boreal tree taxa in the central Scandes during the Late-glacial: implications for Late-Quaternary forest history. *Journal of Biogeography*, 29, 1117-1124.
- Kullman, L. (2008). Early postglacial appearance of tree species in northern Scandinavia: review and perspective. *Quaternary Science Reviews*, 27, 2467-2472.
- Kullman, L. and Kjällgren, L. (2000). A coherent postglacial tree-limit chronology (*Pinus sylvestris* L.) for the Swedish Scandes: aspects of paleoclimate and "recent warming," based on megafossil evidence. *Arctic, Antarctic, and Alpine Research*, 32, 419-428.

- Kvist, R. (1994). The racist legacy in modern Swedish Saami policy. *Canadian Journal of Native Studies*, 14 (2) 203-220.
- Laibner, S. (2000). *Elateridae of the Czech and Slovak Republics*. Kabourek, Zlin.
- Laitinen, J., Rehell, S., Huttunen, A., Tahvanainen, T, Heikkila, R and Lindholm, T. (2007). Mire systems in Finland — special view to aapa mires and their water-flow pattern [Suomen suosysteemit — erityistarkastelussa aapasuot ja niiden Vedenvirtauskuviointi]. *Suoseura — Finnish Peatland Society*, 58 (1) 1-26.
- Landin, B-O. (1961). Ecological studies on dung-beetles. *Opuscula entomologica., Supplementum* 19.
- Lane, S. (1992). *A Provisional Atlas of the Chrysomelid Beetles of Warwickshire*. Warwickshire Museum Service, Warwick.
- Lange, H., Økland, B. and Krokene, P. (2006). Thresholds in the life cycle of the spruce bark beetle under climate change. *InterJournal*, 1648, 1-10.
- Långström, B. and Hellqvist, C. (1993). Induced and spontaneous attacks by *Tomicus piniperda* and *T minor* on young Scots pine trees. *Journal of Applied Entomology*, 115, 25-36.
- Larsson, T. B., Grabowski, R and Ericsson, G. (2009). Arkeologisk delundersökning av boplatsvall, Raä 471:1, Sorsele sn, Västerbottens län. *Umark* 53, Umea.
- Larsson, S.J. and Gígja, G. (1959). Coleoptera. *Zoology of Iceland* 43a. Munksgaard, Copenhagen.
- Lee, J. (1981). Beetles. In *Freshwater Invertebrates of the Sheffield District*. Sorby Record Special Series, 4.
- Legendre, P and Legendre, L. (1998) *Numerical Ecology*. Second English edition. Elsevier, Amsterdam, The Netherlands.
- Lekander, B., Bejer-Petersen, B., Kangas, E. and Bakke, A. (1977). The Distribution of bark beetles in the Nordic Countries. *Acta Entomologica Fennica*, 32, 1-115.
- Lemdahl, G. (1988). A postglacial insect fauna from Skateholm-Järavallen, Southern Sweden. In Larsson, L. (ed.) *The Skateholm Project. 1. Man and Environment. Acta Regiae Societatis Humaniorum Litteratum Lundensis*, 79, 46-51.
- Lemdahl, G. (1997a). Early Weichselian insect faunas from northern Sweden: Climatic and environmental implications. *Arctic and Alpine Research*, 29 (1) 63-74.

- Lemdahl, G. (1997b). Late Weichselian and early Holocene colonisation of beetle faunas in S Sweden. In Ashworth, A.C., Buckland, P. C. and Sadler, J. P. (eds.) *Studies in Quaternary entomology: an inordinate fondness for insect. Quaternary Proceedings*, 5, 153-164.
- Lemdahl, G. (2000). Late-glacial and early Holocene insect assemblages from sites at different altitudes in the Swiss Alps - implications on climate and environment. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 159, 293-312.
- LeSage, L. (1990). *Chaetocnema concinna* (Marsham 1802), a European flea beetle introduced in North America. *Canadian Entomologist*, 122, 647-650.
- Lidmar-Bergström, K., and Näslund, J. (2005). Major landforms and bedrock. In Seppälä, M. (ed.) *The Physical Geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 3-16.
- Liedgren, L. (1997). Den gamla kyrk- och marknadsplatsen i Arvidsjaur, Pite lappmark - mötesplats med medeltida anor. *Norrbottnen*, 2007, 36-53.
- Lindelöw, Å. and Björkman, C. (2001). Insects on lodgepole pine in Sweden - current knowledge and potential risk. *Forest Ecology and Management*, 141, 107-116.
- Lindén, M., Möller, P., Björck, S. and Sandgren, P. (2006). Holocene shore displacement and deglaciation chronology in Norrbotten, Sweden. *Boreas*, 35, 1-22.
- Linder, P. and Östlund, L. (1998). Structural changes in three mid-boreal Swedish forest landscapes, 1885-1996. *Biological Conservation* 85, 9-19.
- Lindroth, C. H. (1931). Die Insektfauna Islands und ihre Probleme. *Zool. Bidr.* 13, 105-589. Uppsala.
- Lindroth, C. H. (1935). The Boreo-British Coleoptera. *Zoogeographica*, 2, 579-634.
- Lindroth, C. H. (1945). *Die Fennoskandischen Carabidae I-II*. Göteborgs K. Vetensk. VitterhSamh. Handl.(6) B, 4. Göteborg. (reprinted as English translation (1992) Intercept, Andover.
- Lindroth, C. H. (1948). Interglacial insect remains from Sweden. *Årsbok Sveriges geologiska undersökning*, C42, 1-29.
- Lindroth, C. H. (1963). The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska. Part 3. *Opuscula Entomologica*, Suppl. 24, 201-408.

- Lindroth, C. H. (1974). Coleoptera: Carabidae. *Handbooks for the Identification of British Insects*, Volume 4 (2). Royal Entomological Society of London.
- Lindroth, C. H. (1985). The Carabidae (Coleoptera) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica*, 15, 1. E.J.Brill, Leiden.
- Lindroth, C. H. (1986). The Carabidae (Coleoptera) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica* 15, 2. E.J.Brill/Scandinavian Science Press Ltd, Leiden/Copenhagen.
- Lindroth, C. H., Andersson, H., Bodvarsson, H. and Richter, S. H. (1973). Surtsey, Iceland. The Development of a New Fauna, 1963-1970. *Terrestrial Invertebrates. Entomologica Scandinavia*, Suppl.5.
- Lindroth, C. H and Coope, G. R. (1971). Appendix 2. The insects from the interglacial deposits at Leveäniemi. *Sveriges geologiska undersökning. Afhandlingar och Uppsatser*, C658, 44-55.
- Lipkow, E. (1992). Staphylinidae (Coleoptera, Aphodius (Coleopteran; Scarabaeidae), and Ptiliidae (Coleoptera) in dung of reindeer (*Rangifer tarandus*) of Northern Finland. *Faunistisch-Ökologische Mitteilungen*, 331-334.
- Ljungberg, H., Andrén, B., Ehnström, B., Jansson, N., Jonsell, M., Lindelöw, Å, Lundberg, S., Malmqvist, A., Nilsson, S. G., Pettersson, R. B., Ramqvist, T., Wanntorp, H-E. And Wikars, L-O. (2010). Skalbaggar – Beetles. Coleoptera. In Gärdenfors, U. (ed.). *Rödlistade arter i Sverige 2010. The 2010 Red List of Swedish Species*. ArtDatabanken SLU, Uppsala, 411-463.
- Lohse, G. A. (1964). Familie Staphylinidae 1. (Micropeplinae bis Tachyporinae). In Freude, H., Harde, K. W. and Lohse, G. A. (eds.) *Die Käfer Mitteleuropas* 4, 7-247. Goecke and Evers, Krefeld.
- Lott, D. A. (2003). An annotated list of wetland ground beetles (Carabidae) and rove beetles (Staphylinidae) found in the British Isles including a literature review of their ecology. *English Nature Report*, No. 488. Peterborough.
- Lott, D. A. and Anderson, R. (2011). The Staphylinidae (Rove Beetles) of Britain and Ireland. Parts 7 and 8: Oxyporinae, Steninae, Euaesthetinae, Pseudopsinae, Paederinae, Staphylininae. *Handbooks for the Identification of British Insects*, Volume 12. Royal Entomological Society.
- Luff, M. L. (1998). *Provisional atlas of the ground beetles (Coleoptera, Carabidae) of Britain*. Centre for Ecology and Hydrology, Biological Records Centre, Abbots Ripton.

- Luff, M. L. (2007). The Carabidae (ground beetles) of Britain and Ireland. Part 2. *Handbook for the Identification of British Insects*, Volume 4. Royal Entomological Society.
- Lundberg, S. (1984). Den brända skogens skalbaggsfauna i Sverige. *Entomologiske Tidsskrift*, 105, 129-141.
- Lundberg, Å. (1997). *Vinterbyar – ett bandsamhälles territorier i Norrlands inland 4500–2500 f. Kr.* Studia Archaeologica Universitatis Umensis 8. Umeå.
- Lundberg, A. (2002). The interpretation of culture in nature: Landscape transformation and vegetation change during two centuries at Hystad, SW Norway. *Norsk Geografisk Tidsskrift - Norwegian Journal of Geography*, 56 (4) 246-256.
- Lundmark, L. (1982). Uppbörd, utarmning, utveckling: det Sámska fångstsamhällets övergång till rennomadism i Lule lappmark. (In Swedish with English summary: Taxation, expropriation and development: the transition of Saami (Lapps) hunting society to reindeer nomadism in Lule Lappmark). Arkiv avhandlingsserie, 14. Doctoral thesis, University of Umeå.
- Lundmark, L. (2007). Reindeer pastoralism in Sweden 1550-1950. *Rangifer*, 12, 9-16.
- Magnus, O. (1555). *A Description of the Northern Peoples*, Vol. I. Translated by Peter Fisher and Humphrey Higgins, and edited by P.G. Foote. London: The Hakluyt Society, 1996.
- Makarova, O. L., Bienkowski, A. O., Bulavintsev, V. I. and Sokolov, A. V. (2007). Beetles (Coleoptera) in polar deserts of the Severnaya Zemlya Archipelago. *Entomological Review*, 87, 1142-1154.
- Manker, E. (1964). *Nomad Year in the North*. Tre Trycare, Cagner and Co., Göteborg.
- Mani, M. S. (1968). *Ecology and Biogeography of High Altitude Insects*. W. Junk, The Hague.
- Manker, E. (1968). *Skogslapparna i Sverige*. Nordiska Museet. Acta Lapponica 18. Stockholm.
- Manseau, M. Huot, J. and Crete, M. (1996). Effects of summer grazing by caribou on composition and productivity of vegetation: community and landscape level. *The Journal of Ecology*, 84 (4) 503-513.

- Martikainen, P., Siitonen, J., Kaila, L. and Punttila, P. (1996). Intensity of forest management and bark beetles in non-epidemic conditions: a comparison between Finnish and Russian Karelia. *Journal of Applied Entomology*, 120 (1-5) 257-264.
- Martikainen, P., Siitonen, J., Punttila, P., Kaila, L. and Rauh, J. (2000). Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. *Biological Conservation*, 94 (2) 199-209.
- Melander, J. (1980). *Rapport över arkeologisk undersökning av fångstgropar, Raä 148 och 468 Gautsträsk, Sorsele sn. Lappland*. Västerbottens museum. Umeå.
- Meriot, C. (1984). The Saami peoples from the time of the voyage of Ottae to Thoman von Westen. *Arctic*, 37 (4) 373-384.
- Merritt, R. (1995). Notable water beetles in Derbyshire: an interim review. *Sorby Record*, 31, 59-65.
- Merritt, R. (2006). Atlas of the water beetles (Coleoptera) and water bugs (Hemiptera) of Derbyshire, Nottinghamshire and South Yorkshire, 1993-2005. *Sorby Record Special Series* 14.
- Moen, J. and Keskitalo, E. C. H. (2010). Interlocking panarchies in multi-use boreal forests in Sweden. *Ecology and Society*, 15 (3) 17. [online]  
URL:<http://www.ecologyandsociety.org/vol15/iss3/art17/>
- Montanarella, L., Jones, R.J.A. and Hiederer, R. (2006). The distribution of peatland in Europe. *Mires and Peat*, 1, 1-10.
- Montelius, S. (1960) Finn settlement in central Sweden. *Geografiska Annaler*, 42 (4) 285-293.
- Morris, M. G. (1977). The British Species of *Anthonomus* Germar (Col., Curculionidae). *Entomologist's monthly Magazine*, 112, 19-40.
- Morris, M. G. (1997). Broad-Nosed Weevils. Coleoptera: Curculionidae (Entiminae). *Handbooks for the Identification of British Insects*, 5, part 17a. Royal Entomological Society, London.
- Mulk, I-M. (1994). *Sirkas. Ett Sámskt fångstsamhälle i förändring Kr. f - 1600 e. Kr.* Studia Archaeologica Universitatis Umensis 6. University of Umeå.
- Munster, T. (1933). Arpedium (Col. Staphylinidae). A revision of the Norwegian species. *Norsk Entomologisk Tidsskrift*, 4 (3) 257-266.

- Muona, J. and Rutanen, I. (1994). The short-term impact of fire on the beetle fauna in boreal coniferous forest. *Annales Zoologici Fennici*, 31, 109-121.
- Nesje, A. (2009). Latest Pleistocene and Holocene alpine glacier fluctuations in Scandinavia. *Quaternary Science Reviews*, 28 (21-22) 2119-2136.
- Niemelä, J. (1997). Invertebrates and Boreal Forest Management. *Conservation Biology*, 11 (3) 601-610.
- Niklasson, M. and Granström, A. (2000). Numbers and sizes of fires: Long-term spatially explicit fire history in a Swedish boreal landscape. *Ecology*, 81 (6) 1484-1499
- Nikolova, B. V. (2007). *Sámi reindeer herders-land and identity. Non-recognition of indigenous land rights-reasons, effects and potential developments*. LUMES master thesis, Lund University.
- Nilssen, A. C., Åsbakk, K., Haugerud, R. E., Hemmingsen, W. and Oksanen, A. (1999). Treatment of reindeer with ivermectin – effect on dung insect fauna. *Rangifer*, 19 (2) 61-69.
- Nilsson, A. N. and Holmen, M. (1995). The aquatic Adephaga (Coleoptera) of Fennoscandia and Denmark. II. Dytiscidae. *Fauna Entomologica Scandinavica*, 32. E. J. Brill, Leiden.
- Nilsson, M., Klarqvist, M., Bohlin, E. and Possnert, G. (2001). Variation in C-14 age of macrofossils and different fractions of minute peat samples dated by AMS. *Holocene*, 11 (5) 579–586.
- Nordlind, E. and Östlund, L. (2003). Retrospective comparative analysis as a tool for ecological restoration - a case study in a Swedish boreal forest. *Forestry*, 76 (2) 243-251.
- Nordström, E-M., Eriksson, L. O., Öhman, K. (2010). Integrating multiple criteria decision analysis in participatory forest planning: Experience from a case study in northern Sweden. *Forest Policy and Economics*, 12, 562-574.
- Öberg, L. and Kullman, L. (2011). Ancient subalpine clonal spruces (*Picea abies*): sources of postglacial vegetation history in the Swedish Scandes. *Arctic*, 64, 183-196.
- Odner, K. (1992). *The Varanger Saami: Habitation and Economy AD 1200-1900*. Scandinavian University Press, Oslo.



- Ohlson, M. and Tryterud, E. (2000). Interpretation of the charcoal record in forest soils: Forest fires and their production and deposition of macroscopic charcoal. *The Holocene*, 10 (4) 519-525.
- Ojala, C-G. (2009). *Sámi Prehistories. The Politics of Archaeology and Identity in Northernmost Europe*. Occasional papers in archaeology 47. Doctoral thesis, Department of Archaeology and Ancient History, University of Uppsala.
- Oksanen, A. (1999). Endectocide treatment of the reindeer. *Rangifer*. Special Issue no. 11
- Olofsson, J. (2009). Effects of simulated reindeer grazing, trampling, and waste products on nitrogen mineralization and primary production. *Arctic, Antarctic, and Alpine Research*, 41 (3) 330-338.
- Olofsson, J., Kitti, H., Rautiainen, P., Stark, S., and Oksanen, L. (2001). Effects of summer grazing by reindeer on composition of vegetation, productivity and nitrogen cycling. *Ecography*, 24, 13–24.
- Olsson, F. (2006). *Holocene forest history at Stavsåkra. Småland, south central Sweden – inferred from insect fossils*. ESS Bulletin, 4, 44-61.
- Olsson, F. (2009). *Structures and Disturbances in Holocene forests of southern Sweden – interpreted from insect and charcoal studies*. Doctoral thesis, School of Pure and Applied Natural Sciences, University of Kalmar, series no. 67.
- Olsson, F., Gaillard, M-J., Lemdahl, G., Greisman, A. and Lanos, P. (2009). Holocene forest fires in the hemiboreal zone of southern Sweden 10,500 calendar years BP to modern time – the role of climate and human activities. In Olsson, F. *Structures and Disturbances in Holocene forests of southern Sweden – interpreted from insect and charcoal studies*. Doctoral thesis, School of Pure and Applied Natural Sciences, University of Kalmar, series no. 67.
- Olsson, F. and Lemdahl, G. (2009a). A continuous Holocene beetle record from the site Stavsåkra, southern Sweden: implications for the last 10 600 years of forest and land use history. *Journal of Quaternary Science*, 24, 612-626.
- Olsson, F and Lemdahl, G. (2009b). A forest history for the last 10,900 years at the site Storasjö, southern Sweden – implications from beetles assemblages. In Olsson, F. *Structures and Disturbances in Holocene forests of southern Sweden – interpreted from insect and charcoal studies*. Doctoral thesis, School of Pure and Applied Natural Sciences, University of Kalmar, series no. 67.

- Østbye, E. and Hågvar, S. (1996). Pitfall catches of surface-active arthropods in high mountain habitats at Finse, south Norway. IV. Coleoptera. *Fauna Norvegica*, B43, 1-18.
- Östlund, L., Zackrisson, O. and Axelsson, A.-L. (1997). The history and transformation of a Scandinavian boreal forest landscape since the 19th century. *Canadian Journal of Forest Research*, 27, 1198-1206.
- Pajunen, A., Virtanen, R. and Roininen, H. (2008). The effects of reindeer grazing on the composition and species richness of vegetation in forest–tundra ecotone. *Polar Biology*, 31, 1233-1244.
- Pakarinen, P. (1995). Classification of boreal mires in Finland and Scandinavia: A review. *Vegetatio*, 118, 29-38.
- Palm, T. (1951). Die Holz und Rindenkäfer der nordschwedischen Laubbaume. *Meddelelser Stat. Skögsfors.-institutet*, 40, no.2.
- Palm, T. (1959). Die Holz und Rindenkäfer der sud- und mittelschwedischen Laubbaume. *Opuscula Entomologica* Suppl. 16.
- Palm, T. (1961). *Svensk Insektfauna*. 9. Skalbaggar. Coleoptera. Kortvingar: Fam. Staphylinidae. Underfam. Oxytelinae, Oxyporinae, Steninae, Euaesthetinae. Entomologiska Föreningen i Stockholm, Stockholm.
- Palm, E. (1996). Nordeuropas Snudebiller. 1. De kortsnude arter (Coleoptera: Curculionidae). *Danmarks Dyreliv* 7. Apollo Books, Stenstrup.
- Parducci, L., Jørgensen, T., Tollefsrud, M. M., Elverland, E., Alm, T., Fontana, S. L., Bennett, K. D., Haile, J., Matetovici, I., Suyama, Y., Edwards, M. E., Andersen, K., Rasmussen, M., Boessenkool, S., Coissac, E., Brochmann, C., Taberlet, P., Houmark-Nielsen, M., Larsen, N. K., Orlando, L., Gilbert, M. T. P., Kjær, K. H., Alsos, I. G. and Willerslev, E. (2012). Glacial Survival of Boreal Trees in Northern Scandinavia. *Science*, 335, 1083-1086.
- Påsse, T. (1998). Lake-tilting, a method for estimation of glacio-isostatic uplift. *Boreas*, 27, 69-80.
- Pavett, P. M. and Levey, B. (2000). New and noteworthy Coleoptera from Wales. *Coleopterist*, 9, 149-154.
- Pearce, E. J. (1957). Coleoptera. Pselaphidae. *Handbooks for the Identification of British Insects*, IV, 9. Royal Entomological Society of London.

- Perry, D. (1981). Cluster analysis of the insect remains from beneath the “raft”. In McGrail, S. (ed.) *The Brigg “raft” and her Prehistoric Environment*. British Archaeological Reports, 89, 176-182.
- Perry, D. (1986). *The Analysis of Sub-fossil Insect remains: A Numerical Approach*. Doctoral Thesis, University of Birmingham.
- Perry, D. W., Buckland, P. C. and Snæsdóttir, M. (1985). The application of numerical techniques to insect assemblages from the Site of Stóraborg, Iceland. *Journal of Archaeological Science*, 12, 335-345.
- Peterken, G. F. (1996). *Natural Woodland Ecology and Conservation in Northern Temperate Regions*. Cambridge University Press, Cambridge.
- Peters, M. E. and Higuera, P. E. (2007). Quantifying the source area of macroscopic charcoal with a particle dispersal model. *Quaternary Research*, 67, 304-310.
- Pitkänen, A., Huttunen, P., Jungner, H. and Tolonen, K. (2002). A 10 000 year local forest fire history in a dry heath forest site in eastern Finland, reconstructed from charcoal layer records of a small mire. *Canadian Journal Forest Research*, 32, 1875-1880.
- Pont, A.C. (2000) Family Fanniidae. In Papp, L. and Darvas, B. (eds.). *Contributions to a Manual of Palearctic Diptera (with special reference to flies of economic importance)*. Appendix 13, 447–454, Science Herald, Budapest.
- Preston, C. D., Pearman, D. A. and Dines, T. D. (2002). *New Atlas of the British and Irish Flora*. Oxford University Press.
- Ranius, T., Kindvall, O., Kruys, N. and Jonsson, B. G. (2003). Modelling dead wood in Norway spruce stands subject to different management regimes. *Forest Ecology and Management*, 182, 13-29.
- Räsänen, S. (2001). Tracing and interpreting fine-scale human impact in northern Fennoscandia with the aid of modern pollen analogues. *Vegetation History and Archaeobotany*, 10 (4) 211-218.
- Ratcliffe, D. (2005) *Lapland: A Natural History*. Poyser, UK.
- Reimer, P. J., Brown, T. A., and Reimer, R. W. (2004). Discussion: Reporting and calibration of post-bomb <sup>14</sup>C data. *Radiocarbon*, 46, 1299–1304.
- Reuss, N. S., Hammarlund, D., Rundgren, M., Segerström, U., Eriksson, L. and Rosén, P. (2010). Lake ecosystem responses to Holocene climate change at the subarctic tree-line in northern Sweden. *Ecosystems*, 13, 393-409.

- Richards, O. W. (1926). Studies on the ecology of English heaths. III. Animal communities of the felling and burn successions at Oxshott Heath, Surrey. *Journal of Ecology*, 14, 244-281.
- Riksantikvarieämbetet (2012) - *Swedish National Heritage Board* [online] Fornsök - The Archaeological Sites and Monuments  
<<http://www.fmis.raa.se/cocoon/fornsok/search.html>>
- Robertsson, A.-M. and García Ambrosiani, K. (1988). Late Pleistocene stratigraphy at Boliden, northern Sweden. *Boreas*, 17, 1-14.
- Robinson, M. A. (1991). The Neolithic and Late Bronze Age insect assemblages. In Needham, S. (ed.) *Excavation and salvage at Runnymede Bridge, 1978: the late Bronze Age waterfront site*. London: British Museum, 277-325.
- Robinson, M., A. (2001). Insects as palaeoenvironmental indicators. In: Brothwell, D. R. and Pollard, A. M. (eds). *Handbook of Archaeological Sciences*. J. Wiley and sons, Chichester, 121-133.
- Ronquist, F. (2010). 250 years of Swedish Taxonomy. In Polaszek, A. (ed.) *Systema Naturae 250 – The Linnaean Ark*. CRC Press, Boca Raton, Florida, 241-252.
- Rosén, P., Segerstrom, U., Eriksson, L., Renberg, I. and Birks, H. J. B. (2001). Holocene climatic change reconstructed from diatoms, chironomids, pollen and near-infrared spectroscopy at an alpine lake (Sjuodjijaure) in northern Sweden. *The Holocene*, 11, 551-562.
- Roturier, S. and Roué, M. (2009). Of forest, snow and lichen: Sámi reindeer herders' knowledge of winter pastures in northern Sweden. *Forest Ecology and Management*, 258 (9) 1960-1967.
- Rozkošný, R., Gregor, F. and Pont, A.C. (1997). The European Fanniidae (Diptera). *Acta Scientiarum Naturalium Academiae Scientiarum aturalium Academiae Scientiarum Bohemicae—Brno*, 31, 1-80.
- Ruong, I. (1944). Något om den gamla skogsrenskötseln i Arvidsjauras socken. *Geographica* 15. Uppsala.
- Ruong, I. (1945). Studier i lappsk kultur i Pite lappmark och angränsade områden. *Svenska landsmål och svenskt folkliv, 1943-44*, 123-194.
- Rydin, H. and Jeglum, J. (2006). *The Biology of Peatlands*. University Press, Oxford.

- Rydström, G. (2009). *Det äldsta Lycksele - Öhn*. Skogsmuseet, Rapport 8. Revised from 2006 version.
- Sadler, J. P. (1991). *Archaeological and Biogeographical Implications of Palaeontomological Studies in Orkney and Iceland*. Doctoral thesis, University of Sheffield.
- Salonen, K., Pulliainen, E. and Koponen, M. (1968). Sex ratios in *Blastophagus piniperda* L. (Col., Scolytidae) in Finland. *Annales Entomologicae Fennicae*, 34, 31-37.
- Salonen, J.S., Seppä, H., Luoto, M., Björne, A.E., Birks, H.J.B. (2012). A North European pollen–climate calibration set: analysing the climatic responses of a biological proxy using novel regression tree methods. *Quaternary Science Reviews* 45 (29) 95-110.
- Savall'ev, D. V. (1968). Control of warble flies and bloodsucking Diptera. In Zhignov, P. S. (ed.) *Reindeer Husbandry*. Translated from Russian. Israel Program for Scientific Translations. Jerusalem, 294-311.
- Schefferus, J. (1674). *The history of Lapland: wherein are shewed the original, manners, habits, marriages, conjurations, andc. of that people*. At the Theater in Oxford.
- Schiegg, K. (2000). Effects of dead wood volume and connectivity on saproxylic insect species diversity. *Ecoscience*, 7 (3) 290-298.
- Schofield, J. E., Edwards, K. J. and Christensen, C. (2008). Environmental impacts around the time of Norse landnám in the Qorlortoq valley, Eastern Settlement, Greenland. *Journal of Archaeological Science*, 35, 1643-1657.
- Segerström, U. (1990). *The post-glacial history of vegetation and agriculture in the Luleälv river valley*. Archaeology and Environment 7. University of Umeå, Dept. of Archeology.
- Segerström, U. (1997). Dynamics of Vegetation and Disturbance of a Southern Boreal Spruce Swamp. *Journal of Vegetation Science*, 8 (2) 295-306.
- Segerström, U. and Emanuelsson, M. (2002). Extensive forest grazing and hay-making on mires- vegetation changes in south-central Sweden due to land use since Medieval times. *Vegetation History and Archaeobotany*, 11, 181-190.

- Segerström, U., Hörnberg, G. and Bradshaw, R. (1996). The 9000 year history of vegetation development and disturbance patterns of a swamp-forest in Dalarna, northern Sweden. *The Holocene*, 6, 37-48.
- Seppä, H. and Birks, H. J. B. (2001). July mean temperature and annual precipitation trends during the Holocene in the Fennoscandian tree-line area: pollen based climate reconstructions. *The Holocene*, 11, 527-539.
- Seppä, H., Birks, H. J. B., Odland, A., Poska, A. and Veski, S. (2004). A modern pollen–climate calibration set from northern Europe: developing and testing a tool for palaeoclimatological reconstructions. *Journal of Biogeography*, 31 (2) 251-267.
- Seppä, H. and Hammarlund, D. (2000). Pollen-stratigraphical evidence of Holocene hydrological change in northern Fennoscandia supported by independent isotopic data. *Journal of Paleolimnology*, 24, 69–79.
- Seppälä, M. (2005). Glacially sculptured landforms. In Seppälä, M. (ed.) *The Physical Geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 35-58.
- Shipman, J. T. Wilson, J. D. Todd, A. and Higgins, C. A. (2012). *An Introduction to Physical Science*. 13<sup>th</sup> Edition, Cengage Learning.
- Shore, J. S., Bartley, D. D. and Harkness, D. D. (1995). Problems encountered with the <sup>14</sup>C dating of peat. *Quaternary Science Reviews (Quaternary Geochronology)*, 14, 373-383.
- Siitonen, J. (2001). Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. *Ecological Bulletins*, 49, 11- 41.
- Siitonen, J. and Martikainen, P. (1994). Occurrence of rare and threatened insects living on decaying *Populus tremula*: a comparison between Finnish and Russian Karelia. *Scandinavian Journal of Forest Research*, 9 (2) 185-191.
- Siitonen, J., Martikainen, P., Punttila, P. and Rauh, J. (2000). Coarse woody debris and stand characteristics in mature managed and old-growth boreal mesic forests in southern Finland. *Forest Ecology and Management*, 128, 211-225.
- Siitonen, J. and Saaristo, L. (2000). Habitat requirements and conservation of *Pytho kolwensis*, a beetle species of old-growth boreal forest. *Biological Conservation*, 94, 211-220.

- Similä, M., Kouki, J., Martikainen, P. and Uotila A. (2002). Conservation of beetles in boreal pine forests: the effects of forest age and naturalness on species assemblages. *Biological Conservation*, 106, 19-27.
- Sjörs H (1965). Forest regions. *Acta Phytogeographica Suecica*, 50.
- Skarin, A., Danell, Ö., Bergström, R. and Moen, J. (2004). Insect avoidance may override human disturbances in reindeer habitat selection. *Rangifer*, 24 (2) 95-103.
- Skidmore, P. (1991). *Insects of the British Cow-Dung Community*. Field Studies Council.
- SMHI (Swedish Meteorological and Hydrological Institute) (2009). *Klimatkarta som illustrerar isläggning för små sjöar < 10 km<sup>2</sup> för den av WMO definierade normalperioden 1961-1990*. Accessed online at <<http://www.smhi.se/klimatdata/hydrologi/is/Normal-islaggning-sma-sjoar-1.8004>> on 16th May 2012.
- SMHI (Swedish Meteorological and Hydrological Institute) (2009a). *Klimatkarta som illustrerar islossning för små sjöar < 10 km<sup>2</sup> för den av WMO definierade normalperioden 1961-1990*. Accessed online at <<http://www.smhi.se/klimatdata/hydrologi/is/Normal-islossning-sma-sjoar-1.8016>> on 16th May 2012.
- SMHI (Swedish Meteorological and Hydrological Institute) (2009b). *Normal första dag med snötäcke, medelvärde*. Accessed online at <<http://www.smhi.se/klimatdata/meteorologi/sno/Normal-forsta-dag-med-snotacke-medelvarde-1.7933>> on 16th May 2012.
- SMHI (Swedish Meteorological and Hydrological Institute) (2009c). *Normal sista dag med snötäcke, medelvärde*. Accessed online at <<http://www.smhi.se/klimatdata/meteorologi/sno/Normal-sista-dag-med-snotacke-medelvarde-1.7935>> on 16th May 2012.
- SMHI (Swedish Meteorological and Hydrological Institute) (2009d). *Normal uppskattad årsnederbörd, medelvärde 1961-1990*. Accessed online at <<http://www.smhi.se/klimatdata/meteorologi/nederbord/1.6934>> on 16th May 2012.
- SMHI (Swedish Meteorological and Hydrological Institute) (2009e). *Normal medeltemperatur för januari, (1961-1990)*. Accessed online at <<http://www.smhi.se/klimatdata/meteorologi/temperatur/1.3976>> on 14th december 2012.

- SMHI (Swedish Meteorological and Hydrological Institute) (2009f). *Normal medeltemperatur för juli, (1961-1990)*. Accessed online at <<http://www.smhi.se/klimatdata/meteorologi/temperatur/1.3991>> on 14th December 2012.
- SMHI (Swedish Meteorological and Hydrological Institute) (2011). *Årsmedeltemperatur*. Accessed online at <<http://www.smhi.se/klimatdata/meteorologi/2.1353/monYrTable.php?month=13&ndpar=tmpYr>> on 16th May 2012.
- Smith, D. M. (2000). Beetle taphonomy in a recent ephemeral lake, southeastern Arizona. *Palaios*, 15 (2) 152-160.
- Smith, D. M., Cook, A. and Nufio, C. R. (2006). How physical characteristics of beetles affect their fossil preservation. *Palaios*, 21 (3) 305-310.
- Smith, D., Whitehouse, N., Bunting, J.M. and Chapman, H. (2010). Can we characterise 'openness' in the Holocene palaeoenvironmental record? Modern analogue studies of insect faunas and pollen spectra from Dunham Massey deer park and Epping Forest, England. *The Holocene*, 20 (2) 215-229.
- Snowball, I., Zillén, L. and Gaillard, M-J. (2002). Rapid early-Holocene environmental changes in northern Sweden based on studies of two varved lake-sediment sequences. *The Holocene*, 12 (1) 7-16.
- Snowball, I., Muscheler, R., Zillén, L., Sandgren, P., Stanton, T. & Ljung, K. (2010). Radiocarbon wiggle matching of Swedish lake varves reveals asynchronous climate changes around the 8.2 kyr cold event. *Boreas*, 39, 720-733.
- Söderholm, W. (1973). *Om tider som svunnit: Historiska glimtar från Lappmarken och Lycksele. En bok tillkommen med anledning av Lyckseles 300-årsjubileum 1973*. Lycksele: kommunen
- Solberg, E. J., Jordhøy, P., Strand, O., Aanes, R., Loison, A., Sæther, B.-E. and Linnell, J. D. C. (2001). Effects of density-dependence and climate on the dynamics of a Svalbard reindeer population. *Ecography*, 24, 441-451.
- Solheim, H., Krokene, P. and Långström, B. (2001). Effects of growth and virulence of associated blue-stain fungi on host colonization behaviour of the pine shoot beetles *Tomicus minor* and *T. piniperda*. *Plant Pathology*, 50, 111-116.
- Sonesson, M. (1974). Late Quaternary Forest Development of the Torneträsk Area, North Sweden. 2. Pollen Analytical Evidence. *Oikos*, 25 (3) 288-306.



- SOU (2007: 60). *Sverige inför klimatförändringarna – hot och möjligheter*. Kapitel 1-3. Ministry of the Environment, Stockholm, Sweden.
- Southwood, T. R. E. and Hendersen, P. A. (1978). *Ecological Methods* (3<sup>rd</sup> edition). Blackwell Science, Oxford.
- Speight, M. C. D. (1989a). *Saproxyllic Invertebrates and Their Conservation*. Council of Europe, Strasbourg.
- Spessivtseff, P. (1925). Scolytidae Svensk Insektfauna. Skalbaggar Coleoptera. Fam. Barkborrar. *Entomologiska föreningen I Stockholm*, 28 (6) 143-195.
- Stainforth, T. (1944). Reed-beetles of the genus *Donacia* and its allies in Yorkshire (Col. Chrysomelidae). *Naturalist*, 81-91, 127-139.
- Stark, S. (2002). Reindeer Grazing and Soil Nutrient Cycling in Boreal and Tundra Ecosystems. *Acta Universitatis Ouluensis: Scientiae rerum naturalium*, 382.
- Statistiska centralbyrån (2011). Protected nature 2010, corrected version 2011-10-18. MI41 *Protected nature*. Statistics Sweden.
- Steel, W. O. (1963). Staphylinidae, Pselaphidae and Scydmaenidae. In, The insects of the Malham Tarn area. *Proceedings of the Leeds Philosophical and Literary Society*, 9, 52-56.
- Stokes, P and Rowley-Conwy, P. (2002). Iron Age Cultigen? Experimental Return Rates for Fat Hen (*Chenopodium album* L.). *Environmental Archaeology*, 7, 95-99.
- Stokland, J. (1994). Biological diversity and conservation strategies in Scandinavian boreal forests. Doctoral thesis, Department of Biology, University of Oslo.
- Strand, A. (1946). *Nord Norges Coleoptera*. Tromsø Museums Arshefter, Naturhistorisk Avd. Nr. 34, 67 (1).
- Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, F. G., van der Plicht, J. and Spurk, M. (1998). INTCAL98 Radiocarbon Age Calibration, 24,000-0 cal BP. *Radiocarbon*, 40 (3) 1041-1083.
- Sundström, H., Vahtola, J. and Koivunen, P. (1981). The earliest settlement in the Tornio (Torne) river valley. An example of inter-disciplinary research. In Gissel, S. Jurikkala, E. Österberg, E., Sandnes, J. and Teitson, B. (eds.) *Desertion and land colonization in the Nordic countries c.1300-1600*. Stockholm, Almqvist and Wiksell, 244-271.

- Suominen, O., Niemelä, J., Marikainen, P., Niemälä, O. and Kojola, O. (2003). Impact of reindeer grazing on ground-dwelling Carabidae and Curculionidae assemblages in Lapland. *Ecography*, 26 (4) 503-513.
- Suominen, O. and Olofsson, J. (2000). Impacts of semi-domesticated reindeer on structure of tundra and forest communities in Fennoscandia: a review. *Annales Zoologici Fennici*, 37, 233-249.
- Sveinbjarnardóttir, G., Erlendsson, E., Vickers, K., McGovern, T. H., Milek, K. B., Edwards, K. J., Simpson, I. A. and Cook, G. (2007). The palaeoecology of a high status Icelandic farm. *Environmental Archaeology*, 12 (2) 197–216.
- Svenning, J.-C. (2002). A review of natural vegetation openness in north-western Europe. *Biological Conservation*, 104, 133–148.
- Tanner, V. (1929). Antropogeografiska studier inom Petsamo-området. I Skoltlapparna. *Fennia* 49 (4). Helsingfors.
- Tegengren, H. (1952). En utdöd lappkultur i Kemi lappmark. *Acta Academiae Aboensis, Humaniora* 19 (4). Åbo
- Thingstad, P. G. (1987). Pitfall trapping of the Carabid fauna in alpine and subalpine habitats at Saltfjellet, North Norway. *Fauna Norvegica*, B34, 105-116.
- Tikkanen, M. (2005). Climate. In Seppälä, M. (ed.) *The physical geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 97–112.
- Tinner, W., Hofstetter, S., Zeugin, F., Conedera, M., Wohlgemuth, T., Zimmermann, L. and Zweifel, R. (2006). Long-distance transport of macroscopic charcoal by an intensive crown fire in the Swiss Alps - implications for fire history reconstruction. *The Holocene*, 16 (2) 287-292.
- Tuittila, E.-S., Välimäki, M., Laine, J. & Korhola, A. (2007). Quantifying patterns and controls of mire vegetation succession in a southern boreal bog in Finland using partial ordinations. *Journal of Vegetation Science*, 18, 891–902.
- Tveraabak, L.U. (2004). Atlantic heath vegetation at its northern fringe in Central and Northern Norway. *Phytocoenologia*, 34 (1) 5-31.
- Utterström, G. (1955). Climatic fluctuations and population problems in Early Modern History. *Scandinavian Economic History Review*, 3, 3-47.

- Väisänen, R., Biström, O., Heliövaara, K. (1993). Sub-cortical Coleoptera in dead pines and spruces: is primeval species compositions maintained in managed forests? *Biodiversity and Conservation*, 2, 95-113.
- van der Linden, M., Barke, J., Vickery, E., Charman, D. J., van Geel, B. (2008). Late Holocene human impact and climate change recorded in a northern Swedish peat deposit. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 258, 1–27.
- Vedin, H. (1995). Air Temperature. In Raab, B. and Vedin, H. (eds.) *Climate, Lakes and Rivers*. National Atlas of Sweden, SNA Publishing, 44-57.
- Velle, G., Brodersen, K. P, Birks, H. J. B. and Willassen, E. (2010). Midges as quantitative temperature indicator species: Lessons for palaeoecology. *The Holocene*, 20 (6) 989-1002.
- Vickers, K. A. (2006). *The Palaeoentomology of the North Atlantic Islands*. Doctoral thesis. Department of Archaeology, University of Sheffield.
- Viklund, K. (1998). *Cereals, Weeds and Crop Processing in Iron Age Sweden. Methodological and interpretive aspects of archaeobotanical evidence*. Archaeology and Environment 14. Umeå.
- Vogel, M., Remmert, H. and Lewis Smith, R. I. (1984). Introduced reindeer and their effects on the vegetation and the epigeic invertebrate fauna of South Georgia (subantarctic). *Oecologia*, 62, 102-109.
- Wagner, P. (1997). Human Impact or Cooling Climate? The "Little Ice Age" and the beetle fauna of the British Isles. In Ashworth, A.C., Buckland, P.C. and Sadler, J. P. (eds). *Studies in Quaternary Entomology - An Inordinate Fondness for Insects. Quaternary Proceedings*, 5, 269-276.
- Warchałowski, A. (2003). *Chrysomelidae. The leaf-beetles of Europe and the Mediterranean area*. Warszawa, Natura optima dux Foundation.
- Weckström, J., Seppä, H. and Korhola, A. (2010). Climatic influence on peatland formation and lateral expansion in sub-arctic Fennoscandia. *Boreas*, 39, 761-769.
- Westerholm, J. (2005). Major human impact. In Seppälä, M. (ed.) *The Physical Geography of Fennoscandia*. The Oxford Regional Environments Series, Oxford University Press, 368-381.
- Wheelerburg, R. P. (1991). Uma Saami native harvest data derived from Royal Swedish Taxation records 1557-1614. *Arctic*, 44 (4) 337-345.

- White, R. G. (1983). Foraging patterns and their multiplier effects on productivity of northern ungulates. *Oikos*, 40 (3) 337-384.
- Whitehouse, N.J. (2004). Mire ontogeny, environmental and climate change inferred from fossil beetle successions from Hatfield Moors, eastern England. *The Holocene*, 14, 79-93.
- Winter, T. G. and Evans, H. F. (1990). *Insects and storm-damaged Conifers*. Research Information Note 173. Forestry Commission Research Division, Farnham.
- Zachrisson, I. (1976). Lapps and Scandinavians. Archaeological finds from northern Sweden. *Early Norrland*, 10.
- Zackrisson, O. (1977). Influence of Forest Fires on the North Swedish Boreal Forest. *Oikos*, 29 (1) 22-32.
- Zackrisson, O., L. Östlund, O. Korhonen, and I. Bergman. (2000). The ancient use of *Pinus sylvestris* L. (Scots pine) inner bark by Sámi people in northern Sweden, related to cultural and ecological factors. *Vegetation History and Archaeobotany*, 9 (2) 99-109.